ROCKLAND

Rockland Scientific Corporation

# Model 660B
# Dual Channel
# Spectrum Analyzer

PART NUMBER 57-02821

ROCKLAND
Rockland Scientific Corporation
10 Volvo Drive, Rockleigh, NJ 07647
TEL: (201) 767-7900

# WARRANTY

Rockland Scientific Corporation ("Rockland") warrants its instruments against defects in material and workmanship for a period of one year after date of manufacture . Rockland agrees to repair or replace any assembly or component (except batteries) found to be defective, under normal use, during this period. Rockland's obligation under this warranty is limited solely to repairing any such instrument which in its sole opinion proves to be defective within the scope of the warranty when returned to the factory or to an authorized service center. Transportation to the factory or service center is to be prepaid by purchaser. Shipment should not be made without prior authorization by Rockland.

This warranty does not apply to any products repaired or altered by persons not authorized by Rockland, or not in accordance with instructions furnished by Rockland. If the instrument is defective as a result of misuse, improper repair, or abnormal conditions or operations, repairs will be billed at cost.

Rockland assumes no responsibility for its product being used in a hazardous or dangerous manner either alone or in conjunction with other equipment. High voltage used in some instruments may be dangerous if misused. Special disclaimers apply to these instruments. Rockland assumes no liability for secondary charges or consequential damages and, in any event, Rockland's liability for breach of warranty under any contract or otherwise, shall not exceed the purchase price of the specific instrument shipped and against which a claim is made.

Any recommendations made by Rockland for use of its products are based upon tests believed to be reliable, but Rockland makes no warranty of the results to be obtained. This warranty is in lieu of all other warranties, expressed or implied, and no representative or person is authorized to represent or assume for Rockland any liability in connection with the sale of our products other than set forth herein.

TABLE OF CONTENTS

PAGE

FORWARD

SHORT FORM OPERATIONS MANUAL FOR 660B

SECTION

1. Overall Specifications . . . . . 1-1

2. General Characteristics of the Front Panel . . . . . 2-1

3. General Characteristics of the Display . . . . . 3-1

4. Operating Mode Controls. . . . . 4-1

5. Frequency Range Controls . . . . . 5-1

6. Input Controls . . . . . 6-1

7. Capture Controls . . . . . 7-1

8. Averager Controls. . . . . 8-1

9. Function Select Controls . . . . . 9-1

10. Display (Channel/Format) Controls. . . . . 10-1

11. Display Scale Controls . . . . . 11-1

12. Display Gain/Unit Controls . . . . . 12-1

13. Cursor Controls. . . . . 13-1

14. Output Type Controls . . . . . 14-1

15. Display Memory Controls. . . . . 15-1

16. Calculation Control Keyboard . . . . . 16-1

17. Power On Conditional States . . . . . 17-1

18. Text Entry . . . . . 18-1

19. Digital Interfaces to the 660B . . . . . 19-1

19.1 Available Interfaces . . . . . 19-1
A. Introduction . . . . . -1
B. IEEE-488 . . . . . -1
C. RS232-C . . . . . -1
D. Parallel A/D. . . . . -2

TABLE OF CONTENTS (Con't.)


SECTION PAGE

19. Digital Interfaces to the 660B (Con't.)

19.2 Using the Interfaces . . . . . 19- 2
A. Selecting Interface Parameters . . . . . - 2
1. Switch Selectable Parameters . . . . . - 2
2. DEFine AUXiliary Selectable Parameters . - 5
B. Types of Information . . . . . - 6
C. Controlling the 660 . . . . . -12
1. Emulating the Front Panel . . . . . -12
2. Additional Remote Commands . . . . . -25
a. Setting Complement Functions . . . . -25
b. External I/O Blocksize Control . . . -25
c. External I/O Initiate Commands . . . -28
d. Front Panel Lock Out . . . . . -28
e. Entry Field Alpha Mode . . . . . -29
f. Invert Characters in Entry Field . . -30
g. Output Status Byte . . . . . -30
3. Acknowledging Commands . . . . . -33

19.3 Accessing Data . . . . . -34
A. Data Buffers Available . . . . . -34
1. Front Panel Settings (Buffer 0). . . . . -37
2. Nonvolatile Memory (Buffer 1). . . . . -37
3. Octave Buffers (Buffers 2 and 3) . . . -48
4. Averager Buffers (Buffers 4, 5, 6, and 7) and Averager Status Buffer (Buffer E). . . . . -48
5. Display Memory Buffers (Buffers 8 and 9) and Display Memory Status Buffer Buffer (Buffer A) . . . . . -48
6. Text Buffer (Buffer B) . . . . . -49
7. Complex Math Buffers (Buffers C and D) . -49
8. General Block (Buffer F) . . . . . -49
9. Calculating and Scaling 660 Data . . . . -59
a. Data Overview . . . . . -59
b. Derived Data Equations. . . . . -59
c. Scaling Formulas. . . . . -62
B. Internal Data Formats . . . . . -68
1. 8-Bit Bytes . . . . . -68
2. 16-Bit Integers . . . . . -68
3. 40-Bit Scaled Integers . . . . . -68
4. 3 Byte Floating Point Numbers . . . . . -68
a. Positive Mantissa, Positive Characteristic . . . . . -69
b. Positive Mantissa, Negative Characteristic . . . . . -69
c. Negative Mantissa, Positive Characteristic . . . . . -69
d. Negative Mantissa, Negative Characteristic . . . . . -69

TABLE OF CONTENTS (Con't.)

SECTION PAGE


19. Digital Interfaces to the 660B

19.3 Accessing Data (Con't.)
C. I/O Formats . . . . . 19-70
1. Selecting Formats and Blockfill . . . . -70
2. Binary Format . . . . . -70
3. Hexadecimal ASCII . . . . . -71
4. Decimal ASCII . . . . . -71
5. Output Terminators . . . . . -72
D. Starting and Canceling I/O . . . . . -73
E. Supplemental Data . . . . . -74

19.4 Connecting to the Interfaces . . . . . -75
A. RS232-C . . . . . -79
B. IEEE-488 . . . . . -79
1. Devices and Interface Lines . . . . . -79
2. Hardware Overview. . . . . -79
3. Introduction . . . . . -82
a. Operation Without a 488 Bus Controller . . . . . -83
b. 660 Hardware Setup . . . . . -83
c. Output Initiation from the 660 via the Front Panel. . . . . -83
d. Output Initiation from the 660 via Remote Control Commands. . . . . -84
e. Operation with a 488 Bus Controller . -85
f. Controller Limitations . . . . . -85
g. Hardware Setup . . . . . -86
h. Software Setup . . . . . -87
C. Connector Control . . . . . -87
1. Control Inputs . . . . . -87
2. Miscellaneous Output Signals . . . . . -87
3. J113 Parallel A/D Input . . . . . -87

19.5 Appendix
A. Using the 660 with SRQ and Serial Poll . . -91
1. Setting the 488 Environment . . . . . -91
2. Decoding the 660 Serial Poll Status Byte . . . . . -92
a. Event Updates . . . . . -93
b. I/O Updates . . . . . -94
c. Command Response Updates . . . . . -94
B. Pin Assignments. . . . . -96
1. IEEE-488 (1978), J111 . . . . . -96
2. RS232-C, J112 . . . . . -96
3. Parallel A/D, J113 . . . . . -97
4. Control Interface, J114 . . . . . -98
C. ASCII Character Set (7-Bit Code) . . . . . -99

TABLE OF CONTENTS (Con't.)


SECTION PAGE

20. Self Test . . . . . 20-1
21. Options. . . . . 21-1

APPENDIX

A. Entry Field Messages and Error Indicators. . . . . A-1
B. Schematic Diagrams . . . . . B-1
C. Application Notes . . . . . C-1


LIST OF TABLES


2-1 Rear Panel Connections . . . . . 2-3
4-1 Available Functions by Mode. . . . . 4-3
8-1 Valid Averaging Modes. . . . . 8-5
8-2 Averaging Operations . . . . . 8-6
9-1 Functions Labels . . . . . 9-3
9-2 Definitions of Functions . . . . . 9-4
10-1 Available Display Formats. . . . . 10-2
13-1 Horizontal Readout at Cursor - FREQ/ORDERS Switch Set to FREQ . . . . . 13-3
13-2 Horizontal Readout at Cursor - FREQ/ORDERS Switch Set to ORDERS . . . . . 13-3
13-3 Cursor Larger Step Size By Display Type. . . . . 13-4
16-1 Calculation Control Key Functions. . . . . 16-8
16-2 Summary of Shift Key Operations. . . . . 16-16
18-1 Summary of Text Line Editing Control Keys. . . . . 18-1


LIST OF FIGURES


19-1 Hexadecimal Switch Settings . . . . . -3
19-2 Location of Switches on Executive Board . . . . . -4
19-3 Summary of Define Auxiliary Series . . . . . -7
19-4 Command Inputs to the Executive . . . . . -13
19-5 Remote Control Commands for 660 . . . . . -14
19-6 Remote Control Commands . . . . . -16
19-7 Additional Remote Control Commands . . . . . -26
19-8 660 Status Byte . . . . . -31
19-9 Data Buffers Available . . . . . -35
19-10 Contents of Data Buffer 0 . . . . . -38
19-11 Contents of Averager Buffer . . . . . -50
19-12 Averager Status Buffer . . . . . -52
19-13 Contents of Display Memory Buffer . . . . . -53
19-14 Contents of Display Memory Status Buffer (Buffer A). . . . . 19-56
19-14A Contents of Text Buffer (Buffer B) . . . . . -58
19-14B Cross Reference, Contents of 660B Buffers. . . . . -66

SECTION PAGE

LIST OF FIGURES (Con't.)

19-15 Internal Number Formats . . . . . -67
19-16 RS232-C Interface . . . . . -76
19-17 Asynchronous Data Format . . . . . -77
19-18 Typical IEEE-488 Bus Configuration . . . . . -80
19-19 IEEE-488 Interface Source and Acceptor Handshake . -81
19-20 A/D Input and Output Data (Real Data) No DRT . . . -89
19-21 660 Response to Commands Received over IEEE-488 Interface . . . . . -95

# INSTRUCTION MANUAL NOTICE

Every effort has been made by the Engineering and Service Departments of Nicolet Scientific Corporation to present accurate, helpful, and readily understood instructions in this manual. Our goal is to assist you in the efficient operation and maintenance of your precision instrument. The following information will facilitate your use of this publication.

## CORRECTIONS:

Sometimes, changes in text or descriptions of circuit design changes cannot be incorporated in the printed manual (and its schematic diagrams). In this event, we provide you with the latest data on the colored pages in this manual following this page. These colored pages cover corrections to the text or to certain of the schematic diagrams, and must be read for the manual to properly reflect the equipment you received.

## DATA COVERING OPTIONAL FEATURES AND SYSTEM CONFIGURATIONS:

Data covering certain optional features of our equipment, or special system configurations are provided in the text. If you have not ordered these options, the corresponding section of the manual does not apply to the equipment you received.

C A U T I O N

CONCERNING RACK-MOUNTING OF EQUIPMENT:

DO NOT ATTEMPT TO RACK-MOUNT THE UBIQUITOUS SPECTRUM ANALYZER, UNLESS SUPPORT BRACKETS OR SHELVES ARE INSTALLED IN THE RACK TO SUPPORT THE UNIT. THE WEIGHT OF THE SPECTRUM ANALYZER (APPROXIMATELY 80 POUNDS, UNCRATED) REQUIRES STRUCTURAL SUPPORT, IN ADDITION TO THE FRONT PANEL MOUNTING BOLTS. SECURING THE SPECTRUM ANALYZER TO THE VERTICAL CHANNELS OF A RACK ONLY THE BY THE FRONT PANEL WILL RESULT IN DAMAGE TO THE EQUIPMENT!

C A U T I O N

# F O R W A R D

This manual provides operating instructions for the Model 660B Dual-Channel FFT Processor. These instructions introduce the Model 660B controls on a function-group/by/function-group basis. The order of control introduction follows the flow of selections in normal operation. It is recommended that these instructions be read in their entirety before attempting to operate the equipment. For those users who may already be familiar with this equipment a Short Form Operations Manual directly follows.

# SHORT FORM OPERATIONS MANUAL FOR 660B

# SHORT FORM OPERATIONS MANUAL FOR 660B


G-0. Overview

G-1. Initial Setup (Getting Started)

G-2. Set Capture Control (Getting Ready to Collect Data)

G-3. Commonly Used Functions (Dual Channel 1K FFT Mode)

G-4. Average (Controls the Averaging Mode)

G-5. Display Formats

G-6. Display Memory

G-7. Output Display Controls and Features (Includes an Explanation of Each Display Annotation Field)

G-8. Calculation Control Features (General Introduction and Fifteen Major Uses)

G-9. Other 660 Features

- A. Digital Plots.
- B. Order Normalization (Order Tracking).

G-10. Other 660 Modes (Besides 1K FFT)

- A. Signal Enhancement Mode.
- B. Channel A 2K FFT Mode.
- C. Correlation Mode.
- D. Probability Mode.

G-11. 660B Features

- A. TEXT Entry (Previously a 660A option).
- B. Variable Offset and Gain in Phase Displays.
- C. Overlap of Dual Displays.
- D. Self-test and Diagnostics.

G-12. 660B Built-in Options

- A. Excitation Source Option -7.
- B. Digital "Zoom" Expansion -2D.
- C. 1/3, 1/1 Octave Analysis -3.
- D. Spectrum Calculation Option -8.

G-13. Summary

## G-1. INITIAL SETUP (GETTING STARTED)

A. Be sure the FREQ/ORDERS switch is set to FREQ (internal sampling clock), the coupling switch to AC or DC, and the polartiy switches to normal or invert. Be sure you are not in HOLD.

B. Choose MODE--Most common will be Dual 1K which means that 1024 time samples will be taken from both Channels A and B. These will yield two 400 line spectra (other modes are discussed below in Section E).

C. Connect input signals to Channels A and B inputs and reduce MAX AMPLITUDE controls to most sensitive value which does not light overload lights.

D. Set FREQUENCY RANGE. Start high to ensure data is not missed.

## G-2. SET CAPTURE CONTROL (GETTING READY TO COLLECT DATA)

A. CONTinuous for random, sinusoidal, or machinery vibration (Hanning$^2$ ($\cos^4$) window is used).

B. TRANsient for transient or impulsive input (flat weighting is used).

C. ARM is used to trigger on transients.

D. HOLD/REL manually stops data sampling. Pressing HOLD/REL a second time either resets the ARM or starts continuous sampling.

E. TRIG LEVEL sets the level of the trigger when in the ARM mode.

## G-3. COMMONLY USED FUNCTIONS (DUAL CHANNEL 1K FFT MODE)

A. INPT TIME displays 1024 time points of each channel for 1K mode and single 2048 point time trace for 2K analysis. This function is particularly useful for observing transients.

B. INSTantaneous SPECtrum displays each spectrum of Channel A, Channel B, or both as they are computed. When HOLD is depressed, the sampling stops and the spectrum displayed is the spectrum of the last time window. Vertical units are volts.

C. RMS SPECtrum displays the averaged spectra of Channels A and/or B. This only functions during and after averaging. Vertical units are volts.

D. Power Spectrum--Same as RMS spec but vertical units are $V^2$.

E. Transmissability--Channel B magnitude divided by Channel A magnitude, that is, real ratio of output power spectrum to input power spectrum.

F. TF--(Transfer Function) displays during and after averaging the frequency response function B/A ($j\omega$) in any of the display formats discussed in the next section.

G. COHerence displays the coherence function between Channels A and B for averaged transfer functions. The coherence function is a real valued function from 0 to 1.0 which indicates the linear causality from input to output. Coherence of 1.0 is perfect. Coherence less than 1.0 indicates there are other system excitations or noise on either the input or output signal, or the system is nonlinear.

H. Impulse Response--IFFT of transfer function--what the response of a system would be to an impulse assuming A = input and B = output of the system.

G-4. AVERAGE (CONTROLS THE AVERAGING MODE)

A. SUM--Can compute from N = 1 to 9999 spectrum averages. The default number is 16 and may be changed by depressing the following keys on the CALCULATION CONTROL: The number of averages N, SET/STORE, AVGN.

B. DIFF subtracts N spectra from a previous average.

C. EXponential is similar to RC averaging and continually updates data. The effective RC time constant is T = N TIME WINDOWS (sec), where N is Avg N.

D. PK saves the maximum amplitude of each frequency window during spectrum averages.

E. SWEEP averages with maximum overlap or maximum redundancy--normally not used.

F. TRAN averages spectra of N transients automatically in SUM, DIFF, EX, or PK modes. It automatically selects a FLAT window and rearms the capture control after each inut. Signals which overload the input are automatically rejected.

G. START erases the memory and averages until N averages are taken.

H. STOP halts averaging.

I. CONT resumes averaging until N is reached.

G-5. DISPLAY FORMATS
(See Tables 9-1 AND 9-2 for applicable functions.)

A. Channel:

1) A--Channel A only

2) B--Channel B only

3) A/B--Channels A and B

B. Formats:

1) NYQuist--A cross plot of Real and Imaginary components which indicates a polar plot of frequency response or "orbit diagram." (Be sure to set vertical and horizontal display scales to the same range by turning CURSOR OFF and adjusting GAIN toggles.)

2) X PROP--Automatically selected for functions which are two channel cross properties.

3) REAL, IMAG, R/I, REAL and/or IMAGinary components of cross spectra and transfer functions.

4) MAG, $\phi$, MAG $\phi$, Magnitude and/or phase angle of a cross spectrum or transfer function.

G-6. DISPLAY MEMORY

A. STOre retains one 800 line spectrum, one 1024 t time waveform, or two 400 line spectra. For the display of cross-spectrum or TF, stores REAL and IMAG terms regardless of display.

B. ReCalL displays stored data when LED is on. Pressing a second time reverts back to current display (LED off).

C. COMP displays one stored trace and corresponding current trace if both processed in a similar manner.

D. EQL TF/TM divides current spectrum magnitude by stored spectrum magnitude and subtracts the stored phaseangle from the current angle. Also equalizes impulse response and transmissibility. This allows effects introduced by imperfect transducers to be gotten rid of. (Performs complex divisions.)

. OUTPUT DISPLAY CONTROLS AND FEATURES (INCLUDES AN EXPLANATION OF EACH DISPLAY ANNOTATION FIELD)

A. Scales--Selects linear or log amplitude and linear or log amplitude and linear or log frequency. Scales are fixed for coherence (0-1).

B. Display GAIN toggle switches.

1) UP raises trace.

2) DOWN lowers trace.

Use upper toggle switch for upper trace of all dual traces except $\phi$/MAG where this switch controls MAGnitude.* Upper toggle controls gain of all singl trace displays and horizontal scale of NYQ display.

C. Amplitude units--This section determines the units of spectrum data during CURSOR readout.

1) dB/LIN--Either dB or Linear scale on vertical ax

2) V/EU--Vertical axix labeled in volts per divisio or in engineering units (see calculation control

3) ABS/REL--ABS reads absolute amplitude at the CURSOR. REL gives the relative amplitude between two CURSOR locations (see calc. control).

4) PER Hz--Used for Power Spectrum only.

D. CURSOR Type

1) OFF--no CURSOR--full scale amplitudes are annotated on the display.

2) Single--normally used--amplitudes at CURSOR are annotated on display.

3) Harmonic--all multitudes of CURSOR position will be brightened on the display.

E. Display notation (see attached displays)

1) A--Error messages, keyboard entries and settings (number of averages, delay times, etc.).

2) B--CURSOR position on the horizontal axis,

* 660B: When viewing phase only, single or dual trace, upper trace controls phase center, lower trace controls expansion.

normally seconds in time domain, Hz in frequency domain. (See Table 13-1 for other possibilities.)

3) C--Vertical amplitudes at the CURSOR for the upper and lower plots, respectively or when CURSOR is turned off, the full scale range of upper and lower channels.

4) D--Vertical scale VLG = Log, VLN = Linear

5) E--Capture control settings C--CONT, T--TRAN

6) F--Top display trace channel and format: possible formats R--REAL, P--Phase, M--Magnitude, I--IMAGinary. Channel does not appear for Cross Prop's like TF.

7) G--Type of averaging and number of averages. SU = SUM, PK = PEAK, EX = EXponential, DF = Difference, SW = SWEEP, T in front of the other abbreviations indicates Transient averaging, i.e., TSU, TPK, etc.

8) H--Function type, see Table 9-1 for all abbreviations. TF = Transfer function, RS = RMS spectrum, COH = Coherence, IT = Instantaneous time, E prefix = Equalization, D postfix = Density.

9) I--Same as F only for lower trace.

10) J--Max Amplitude setting for Channels A and B respectively. D = DC, A = AC, T = Test.

11) K--Transient trigger source and level, i.e., A/16 = Channel A at FS/16.

12) L = Horizontal scale units.

13) M--Horizontal full scale.

## G-8. CALCULATION CONTROL FEATURES (GENERAL INTRODUCTION AND FIFTEEN MAJOR USES)

A. General--Settings are always made in the following order:

1) Enter number.

2) Depress SET/STORE.

3) Depress appropriate panel button.

B. To recall or annotate a setting

1) Enter number.

2) Depress RECALL.

3) Depress appropriate panel button.

C. In order to

1) Change number of averages: enter number of averages, press SET/STORE, press AVGN. The number of averages will appear in display position A.

2) View number of averages: press RECALL, AVGN

a) when not averaging, shows setting

b) when averaging, shows number of averages completed.

3) Saving CURSOR location--good when you wish to return often to a specific frequency. Enter number from 1-9, press SET/STORE, and CUR LOC. To recall CURSOR, enter number from 1-9, press RECALL and CUR LOC.

4) Store panel settings--even after machine is turned off. A total of 9 panel settings can be stored, enter 1-9, press SET/STORE, press PNL--Beware: The frequency range and input max amplitudes will be those stored in panel, not those set on analyzer. Just rotate the amplitude and frequency knobs to change.

5) Locate the leading edge of a transient in any location in the time window. Enter--number (-1.000 to 63.000) where the three decimal numbers are the fraction of th total window. If you want the transient at the 10% location, Depress: -.100, SET/STORE, DLYT → A. Showing later time greater than the first memory period may be determined by entering up to 63 memory periods of delay. Use RECALL to read number being used.

6) To set time delay between Ch A and Ch B, the capture procedure is similar to the above only positive numbers from 0.000 to 64.000 are available.

7) Measure and display in engineering units--set display so only the channel being set is viewed

i.e., either Ch A or Ch B. Enter number of volts/engineering unit, press SET/STORE, press V/EU to establish setting. To enter value at CURSOR as calibration in engineering units, enter number, press SET/STORE and LIN. The amplitude units buttons determine which settings are applied.

8) Use the Zoom FFT for Frequency expansion--enter desired Bandwidth on keyboard, press SET, XPND WiDTH. Enter center frequency on keyboard, press SET, XPND.

Possible expansion ratios are 8, 16, 32, 63, 125, 250, and 500. Any number may be entered, but the analyzer will always go to the next lowest of the above numbers.

Both XPND and XPND WiDTH are cleared with the CLEAR button. (To expand around the CURSOR press CLEAR, SET, XPND. The CURSOR frequency will be used as the center frequency.)

When the XPND is activated, the upper and lower frequency limits of the expansion window are annotated in the upper left of the display. Pressing RECALL, XPND will recreate this annotation if the expander is on. If the expander is not on, RECALL, XPND will turn it on using the same center frequency as the last expansion used.

For further information, see pages D1-D5 in the back of the 660 Manual.

9) Set calibration at CURSOR to a known dB level; enter no. of dB, press SET/STORE, dB.

10) Calculate RMS Power between two frequencies:

a) View RMS Spectrum.

b) Put CURSOR on 1st frequency and press 1, SET, CUR LOC.

c) Put CURSOR on 2nd frequency and press 2, SET, CUR LOC.

d) Press CLEAR, RECALL, RMS 1→2.

Notes:

a) You may use other stored CURSOR locations than 1 and 2. If the two frequencies are stored CURSORS 5 and 8 for example, press 58, RECALL, RMS 1→2.

b) The power at the limit cells is included in the computation.

c) If you are viewing a power function (power spec, cross spec, coherent output power) then RMS 1→2 calculates mean-square power, not root mean square power. Take square root to get RMS.

.1) Pseudo integration and differentiation--mainly used to compute velocity and displacement from acceleration--only works in the frequency domain. Multiplies amplitude by $1/\omega$ or $1/\omega^2$ when integrating.

Enter number of integrations or derivatives (0, 1, or 2), press SET, and either ∫dt or d/dt. The number of integrations or derivatives can be found by pressing RECALL, ∫dt or d/dt.

12) Coherence Blanking--results in blanking of all transfer function data when coherence value is below a given level.
To set level, enter number from .000 to.999, press SET/STORE, COH BLaNK.

a) To view level, press RECALL, COH BLaNK.

b) To remove, press CLEAR, COH BLaNK.

13) Range of Log (dB) display--enter total range (20 to 160 in 20s), press SET/STORE, DSPL dB. Can be checked with RECALL and deleted with CLEAR.

14) Read frequency relative to a reference--place CURSOR at reference frequency and enter a reference number (0 to $10^5$), press SET/STORE, FREQ REF. All subsequent frequency readings at the CURSOR will add the reference number.

15) Read multiples of a reference frequency--locate CURSOR and enter its multiple to reference (number from .0001 to 99.9999) and press SET/STORE, ORD REF. All subsequenct frequency readings at the CURSOR will be multiples of the set reference order. IF the frequency reads switch is in the ORDERS position.

## G-9. OTHER 660 FEATURES

A. Digital Plots

Exactly what you see on the 660's display can be reproduced on a Nicolet 136A or Tektronix 4662 Digital Plotter.

1) Connect the plotter to the 660 using the RS-232C Interface.

2) Make sure baud rates and parity settings match. (See Figure 19-1 for setting these parameters in the 660.)

3) Press 1, SET, DEF AUX. (This is the default state.)

4) Set upper right and lower left on your plotter. (You may use "AUX, PLOT CAL" to find graticule corners.)

5) Press AUX, PLOT.

Only the last step is necessary to start each plot. The first three are set up.

B. Order normalization (order tracking):

If a machine changes speed while the 660 is averaging it's spectrum, the spectrum will be smeared. This smearing is eliminated when the 660 sampling speed is proportional to the machine's speed. To accomplish this (called order tracking):

1) Set the FREQ/ORDERS switch to ORDERS.

2) Connect a tachometer's pulse output to the 660's ORDERS INPUT. The highest order on the display will be (# pulses per revolution/2.56).

Note:

When the FREQ/ORDERS switch is in the ORDERS position the 660 takes one sample for each pulse on the ORDERS INPUT connector. The internal sampling clock is disabled. If there are no pulses coming in, the 660 will appear dead.

To make the cursor annotation correctly read orders

1) Set the FREQ READS switch to ORDERS.

2) Put the cursor at a known point on the horizontal axis (for example, the rightmost cell = # pulses per revolution/2.56).

3) Enter the known value and press SET, ORD REF.

For example, if the tachometer puts out 32 pulses per machine revolution, the rightmost displayed cell is 12.5 orders. So, with the CURSOR on the rightmost cell, you would press 12.5 SET, ORD REF.

The CURSOR position will now be correctly annotated in ORDERS.

Warning:
The frequency range switch selects the anti-aliasing filter. Be sure to pick the correct range. For example, if your tachometer outputs 32 pulses per machine revolution, and the machine will rotate at approximately 2000 RPM, the 660 will take 2000 x 32 = 64,000 samples per minute = 1067 samples per second. The frequency range (= anti-aliasing filter) selected should be less than or equal to 1067/2.56 = 417. So in this case, the 200 Hz range would be used. Use of a higher range will cause aliasing. The antialiasing filters are -3dB at frequency range +10%, so data above order 6 (200/417 x 12.5 orders = 6 orders) will be attenuated. If you are going to be doing a great deal of order tracking, or if you expect the machine speed to vary greatly, yu will need Nicolet's Model 24C Spectrum Tracking Adapter with its optional Tracking Anti-Aliasing filter.

## G-10. OTHER 660 MODES (BESIDES 1K FFT)

Below, the 660 modes will be discussed (other than Dual 1K, which has already been discussed).

A. SIG ENH (Signal Enhancement Mode):
In this mode, the time histories are averaged instead of frequency spectra. Time averaging must be done synchronously (i.e., triggered by the capture controls). Signals that are not synchronized with the trigger will eventually average to zero, while signals that are synchronized with the trigger will add constructively with each average. This can be useful for seeing frequency components of a machine's spectrum that are multiples of the shaft speed. Without time averaging, these signals may be masked by non-periodic disturbances.

Note:
A relatively large number of averages may be required to significantly enhance the periodic signals.

1) Functions available in this mode:
Instant Time, Averaged Time, and Averaged Time Spectrum (INST SPEC button).

2) Averager modes available in this mode:
Summation (usually used), Difference, Exponential; with TRAN modifier.

B. Channel A 2K FFT Mode:

In this mode, the 660 functions as a single channel analyzer with twice its usual baseband resolution: time histories are 2048 points, a spectrum contains 800 points.

1) Functions available in this mode:
Input Time, Instant Spectrum, (Averaged) RMS spectrum, (Averaged) Power Spectrum.

2) Averager modes available in this mode:
All.

C. Correlation Mode:

Similar to Dual 1K but optimized for Cross Correlation and Auto Correlation functions. Cross Correlation is defined as Channel A's time history convolved with Channel B's, while Auto Correlation convolves each channel's time history with itself. The result shows the similarity of a signal to the signal it was convolved with delayed by $\tau$ (indicated by the CURSOR). For information on interpreting the results, including calculation of "correlation coefficient," please see Table 9-2.

1) Functions available in this mode:
Only Auto Corr, Cross Corr, and Instant Time are recommended.

2) Averager modes available in this mode:
All

D. Probability Mode:

In this mode, the averager averages the occurance of each possible amplitude level. The Probability Density function shows relative probability that a signal was at a certain amplitude. Cumulative distribution function shows the probability that the amplitude of your signal was at or below a value x. For both these functions, the horizontal axis is voltage from -Attenuator setting to +Attenuator setting. Vertical units for CDF are probability, from 0 to 1. PDF is defined as the derivative of CDF by voltage, so its vertical axis goes from 0 to 64/Attenuator setting; units are $V^{-1}$.

Functions available in this mode:
Cumulative Distribution Function (CDF),
Probability Density Function (PDF), Instant Time.

## G-11. 660B FEATURES

A. Text Entry:

Allows four lines of up to 44 characters to be entered, edited, and positioned anywhere on the display. Press the TEXT button (plus TEXT 2, 3, or 4 for those fields) and enter or edit the field using the TEXT entry keypad. The cursor (left-right joystick) controls are used to move the text cursor or, if SHIFT 1, 6 is pressed, to move the text field. For further information, please see Section 18 of the 660B manual.

Text entry was an option on the 660A.

B. Variable Offset and Gain in Phase Displays:

Phase is usually displayed with the top and bottom of the display at plus and minus 180° respectively. For data near ±180°, this can be a disadvantage. Also, small changes in phase may be hard to see.

These problems are solved on the 660B when Phase only(φ)is viewed. In this case, the upper gain toggle will "roll" the phase display and the lower gain toggle will increase the gain. With the cursor off, "center/vertical graticule division size" is annotated in degrees. With the cursor on, phase at cursor is annotated.

C. Overlap at Dual Displays:

Dual displays are usually presented one above the other. Pressing the OVLP button will overlap the displays for easier comparison. Pressing OVLP again will return the display to its normal state.

Phase/Mag cannot be overlapped.

D. Self-Test and Diagnostics:

A switch on the 660B's Main Memory board selects either the usual program or the self-test program. The self-test program checks front panel operation, memory, program, operation of all processors and the hardware multiplier, and more. It is fully covered in Section 20 of the 660B manual.

## G-12. 660B BUILT-IN OPTIONS

Note:
All the Options covered below are covered in detail in Section 21 of the 660B manual.

A. Excitation Source Option -7:

Before covering Option -7, note that all 660s have a binary noise output on J 110 on the rear panel. This standard noise source is always 0-1 V Peak to Peak, from essentially DC to frequency range setting. It is not a calibrated signal but should be flat within 2 or 3 dB. All 660s also have filtered noise out (J 104) which is the same noise with a notch at approximately 55% of the frequency range. This is essentially a test signal.

Option -7 provides several more advanced features. Its function is selected by the 40 series of Define Aux codes:

40 - Excitation off (Default).
41 - Sine wave out at cursor frequency.
42 - Pseudo-Random Binary Noise.
43 - Periodic Binary Noise.

Output appears on J 109.

1) Sine Wave at Cursor - Sine wave at the cursor frequency. Resolution of .25 Hz, Baseband, or DRT.

2) Pseudo Random Noise - Flat ±3dB of spectral mean across analysis range. When DRT (XPND) is on, noise is Band Limited to concentrate energy inside the analysis window

3) Periodic Noise - Similar to above, but a 1024 or 2048 pt repeating noise pattern, synchronized to data collection.

4) Amplitude of the three functions is variable from 0-9.9 V Peak in 100 mV steps, using 100 to 199 set DEF AUX.

Peak Amplitude = (N - 100) x 100 mV.

B. Digital Expansion or DRT (Digital Range Translation) was covered in Section G-8.C.8. of this document.

C. Octave is a Mode Modifier to the DUAL 1K or CHAnnel A 2K modes. What happens when the Octave button is pushed is controlled by the 200 series of DEF AUX codes as follows:

| | # of Passes | 1/3 or 1/1 | A-weighting |
|---|---|---|---|
| 200 | 1 | 1/3 | OFF |
| 201 | 2 | 1/3 | OFF |
| 202 | 1 | 1/1 | OFF |
| 203 | 2 | 1/1 | OFF |
| 204 | 1 | 1/3 | ON |
| 205 | 2 | 1/3 | ON |
| 206 | 1 | 1/1 | ON |
| 207 | 2 | 1/1 | ON |

Number Passes:
1 Pass computes 5 1/1 octave bands or 15 1/3 octave bands, looks like half a spectrum (left half is zeroed). 2 Pass computes 10 1/1 octave bands or 30 1/3 octave bands. This takes longer and requires automatic switching of frequency range setting.

1) Functions avalable:
INPuT TIME, INSTant TIME, RMS Spec, Power Spec, TF, COH, TM, COP, Cross Spec. Obviously, cross functions are not available in Channel A 2K mode. (Please read the Option -3 part of Section 21 for additional details.

D. Spectrum Calculation Option -8
This option has five major features:

1) Data Editing on data in C.

2) Complex or Scalar Arithmetic.

3) Forward or Inverse FFT on data in C.

4) Special functions, such as damping factor calculation.

5) Force/ Response windows

Note:
"C" is a data buffer used to hold results of Option -8 features.

1) Data Editing:
When viewing C in either the frequency or time domain, one may

a) Insert a value at the cursor: value, SHIFT 2, 5.

b) Draw a straight line between stored cursor locations 1 and 2: SHIFT 2, 6.

Both these functions affect the data in C in a manner consistant with the display format.

REAL - Only Real data affected (CR).
IMAG - Only Imaginary data affected (CI).
REAL & IMAG - Both affected.
MAG or $\phi$ MAG - Magnitude is changed by multiplying both Real and Imaginary data by the appropriate factor to achieve the desired result. This preserves phase ($\tan^{-1}$ Imag/Real).

2) Complex or Scalar Math:
Equations in TEXT Field 1, written in a simple but powerful character set permit the manipulation of all 660B data buffers. The character set is

Complex Data Sources:

A - Instantaneous A.
B - Instantaneous B.
C - "Complex Math" result buffer.
D - Display Memory buffer.
V - Averaged Cross Spectrum (Buffers 5,6).
T - Transfer function (computed dynamically).

Scalar Data Sources:

Any of the single letters above may be followed by

R - Real part.
I - Imaginary part.

M - Magnitude ($\sqrt{R^2 + I^2}$).

In addition

VA - Averaged Power Spectrum of A.
VB - Averaged Power Spectrum of B.

Two Source Operators

\+ - Addition
\- - Subtraction
x - Multiplication (SHIFT 2, MULT)
/ - Division (SHIFT 2, DIV)

Single Source Operators:

$\sqrt{\ }$ - Square Root (for example, $\sqrt{VA}$)
# - Conjugate (for example, B#)

Other Characters:

)> - Right Parenthesis
(< - Left Parenthesis (may nest 4 sets deep)
: - Equation terminator. All after = comment
, - Comma = numerical separator
. - Decimal point
E - Letter "E" - Exponent follows for floating point notation (E±XX)
0-9 - Numerics

3) Forward or Inverse IFFT on Data in C:

While viewing C, IFFT may be pressed to perform an IFFT on (what is assumed to be) complex spectral information in C. Pressing IFFT again, or exiting view C, will perform an FFT on the contents of C.

Warning:

The FFT is an Approximation to the integral Fourier transform. Non-repetitive time windows or sharp transitions in time will cause errors. All errors will be exaggerated if transformed back and forth several times.

4) Special Functions:

Some data manipulations that could not be entered as equations have been included in Option -8. For example, "SC" computes absolute value of each point of data in Buffer C. To use a special like "SC", the two letter code would be typed into the TEXT 1 Field, verified, and executed.

The most used "special" has been implemented on the front panel; it is calculation of damping factor. This is done as follows:

a) Set CURSOR to -PEAK in TF real below resonance: Press 1, SET, CUR LOC.

b) Set CURSOR to +PEAK in TF real above resonance: Press 2, SET, CUR LOC.

c) Press SHIFT 2, 9 to calculate damping.

For more information, please see Section 21, pages S-23 - S-29, of the 660B manual.

5) Force/Response Windows:

This feature will be covered on pages G-20 and G-21.

An Example:

It is extremely difficult to construct one example to show the use of every feature of Option -8. Therefore, a short scenario is presented below involving several features:

Part 1:

A structure housing a motor has just been constructed and it is necessary to make sure that the structure will not fly apart when the motor is turned on.

Solution:

Impact Testing: Mode = 1K FFT, get TF. Damping factor can be calculated for each resonance. They should be greater than 1.

Part 2:

The transfer function obtained above has an unexpected peak. Furthermore, the impulse response appears predictive. You would like to eliminate the peak and see the impulse response.

Solution:

Edit the data. First, copy the TF into C: While looking at TF, press STO C. (Press 211, SET, DEF AUX so that C is not formatted as power when you view it.) Now press VIEW C. To eliminate the peak, put the CURSOR on one side of it and press 1, SET, CUR LOC, then put the CURSOR on the other side and press 2, SET, CUR LOC. Press SHIFT 2, 6. This does linear interpolation which will eliminate the peak. Now that you have a modified TF, just press IFFT to see the Impulse Response.

Part 3:

You have decided to repeat the above test in Signal Enhancement made. Any signal not synchronized with the impacts will average to zero. After several hundred impacts, you can see from the Average Time Spectra that things look good, but you would like to see a transfer function.

Solution:

Calculate TF.

a) Press "CM" to enable Complex Math. The "TEXT" light comes on.

b) On the text pad, enter "C/D": (Note: the "/" is SHIFT 2, DIV). Turn off TEXT.

Note:
Executing an equation each pass of the averager does decrease the real time rate of the analyzer.

Part 5:
The involvement now is in impact testing the shaft to discover its resonances. Unfortunately, the shaft rings like a bell. Its oscillations do not die out by the end of the time window. This violates an assumption of the Fast Fourier Transform: the time window must be periodic. That is, if it's zero on the left, it must be zero on the right. The fact

that the oscillations are truncated on the right of the window introduces errors in the frequency domain.

Solution:
Setting up the 660B's Force and Response windows smoothly (exponential decay) forces the response to nearly zero by the end of the time window. This eliminates the garbage at the expense of some spreading of the spectrum. As an added bonus, when F/R windows are enabled, the Complex Math package provides special data handling which greatly increases the dynamic range of DRT (DRT=XPND).

Here is an example of using F/R windows:

a) You must be in CM. Press "F/R".

b) Look at a captured impulse, set CURSORS 1 and 2 to each side of the impulse (see VIII.9). Do not chop off any part of the impulse.

c) Display Channel B (response). Set CURSOR 3 to the beginning of the exponential window. Set CURSOR 4 to the right of CURSOR 3. This defines 1 time constant for the exponential decay.

d) Set up your averager mode.

e) Type "SW:" into Text Field 1.

f) Verify. This draws the Force and Response windows; It also sets up the commands which implement the use of these windows.

Note:
SW is a canned, live equation. Restrictions about not changing Averager mode, AVG N, attenuator settings, EU/V etc. apply. One must re-verify if something that affects scaling is changed.

This feature is available in baseband or DRT.

Once SW has been verified, the windows are in use. The function "F/R" was only for convenience in setting up the windows. You may press another function. The windows will still be in use until one exits complex math or verifies a different equation. Unlike other live equations, SW affects time data. Its effect is visible on all functions, not just on averaged data.

This ends a brief look at Spectrum Calculation Option -8. The reading of pages S-ϕ to S-32 in Section 21 of the 660B manual is for more information is strongly urged.

## G-13. SUMMARY

One should now have a good grasp of what 660 is capable of and how it can be done.

Sections I through VIII told of how to get started in 1K FFT mode and pointed out only the most used functions and features.

Sections IX discussed order tracking.

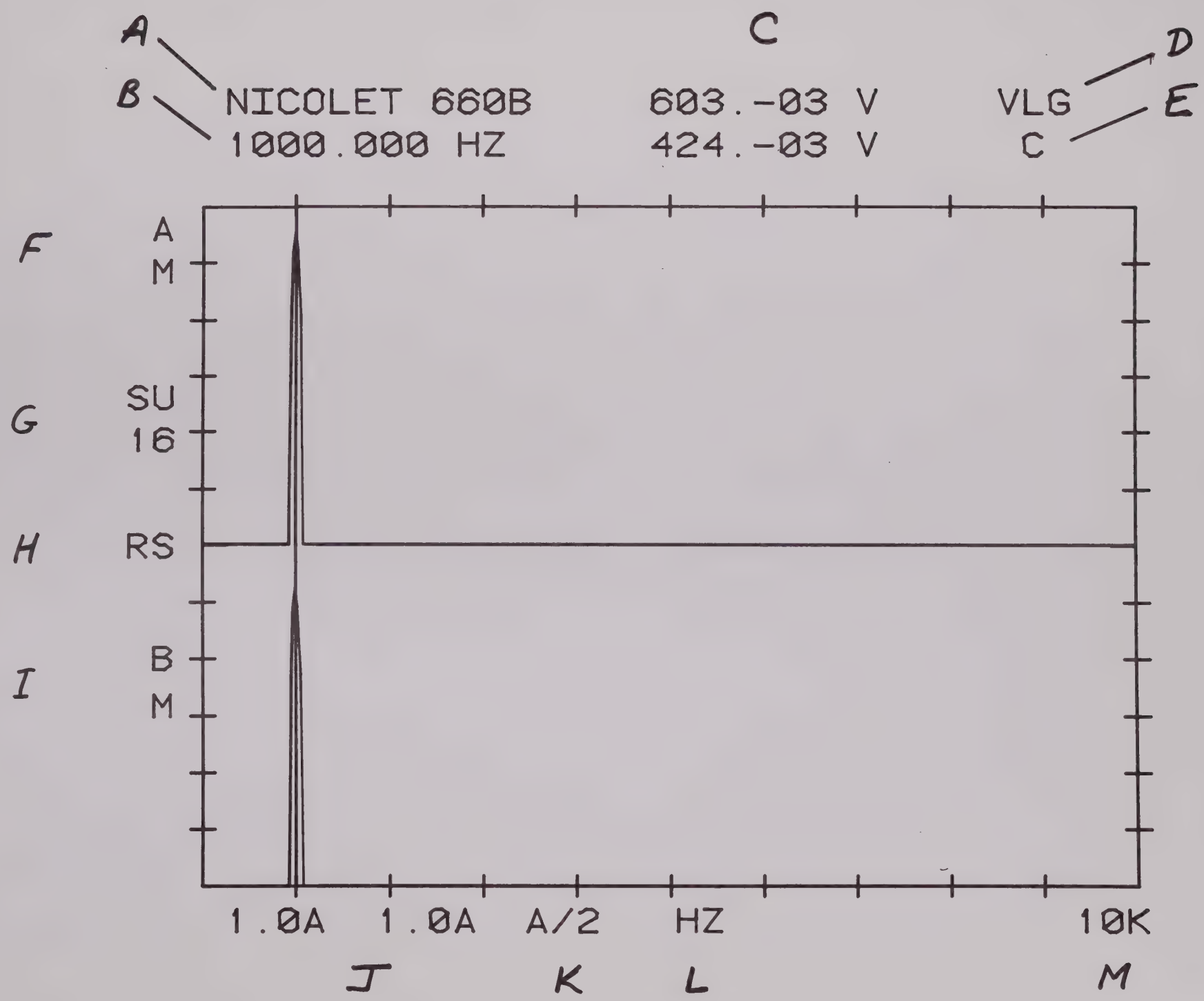
Section X covered the other 660B modes and their uses.

Section XI covered 660B features and Section XII covered the 660B's options.

Sections I-VIII should provide enough information for you to start using a 660 effectively, while Sections IX-XII point out specific features to solve specific problems. If one has read all of this, nearly all of the power of a 660B has been shown. We hope you enjoy using it.

Remember that for more information on any subject, refer to the 660B manual. Some subjects not covered here at all are covered in detail in the 660B manual

(for example, Digital Input/Output is the subject of Section 19).


A
B
NICOLET 660B
1000.000 HZ
C
603.-03 V
424.-03 V
D
VLG
E
C
F
G
H
I
A
M
SU
16
RS
B
M
1.0A
1.0A
A/2
HZ
10K
J
K
L
M

SECTION 1

OVERALL SPECIFICATIONS

| FUNCTIONS CALCULATED AND DISPLAYED | FIVE MEASUREMENT MODES (Traces x no. of data points displayed in each) | | | |
|---|---|---|---|---|
| | #1 SIG ENH | #2 CHA 2K | #3 Dual 1K or #4 CORR[3] | #5 PROB |
| Input Time History (IT) | 2x1024[1] | 1x2048 | 2x1024[1] | 2x1024[1] |
| Averaged Time History (AT) | 2x1024[1] | | | |
| Averaged Time Spectrum (ATS) | 2x400 | | | |
| Instant Spectrum of Input (IS) | | 1x800 | 2x400 | |
| RMS Spectrum (RS) | | 1x800 | 2x400 | |
| Power Spectrum (PS) | | 1x800 | 2x400 | |
| Cross Spectrum (CS) | | | 1x400[2] | |
| Transfer Function (TF) | | | 1x400[2] | |
| Equalized Transfer Function (ETF) | | | 1x400[2] | |
| Transmissibility Function (TM) | | | 1x400 | |
| Equalized Transmissibility Function (ETM) | | | 1x400 | |
| Coherence Function (COH) | | | 1x400 | |
| Coherent Output Power (CP) | | | 1x400 | |
| Impulse Response (IR) | | | 1x1024 | |
| Equalized Impulse Response (EIR) | | | 1x1024 | |

| FUNCTIONS CALCULATED AND DISPLAYED | FIVE MEASUREMENT MODES (Traces x no. of data points displayed in each) | | | |
|---|---|---|---|---|
| | #1 SIG ENH | #2 CHA 2K | #3 Dual 1K or #4 CORR[3] | #5 PROB |
| Auto Correlation Function (ACF) | | | 2x1024[4] | |
| Cross Correlation Function (CCF) | | | 1x1024[4] | |
| Probability Density Function (PDF) | | | | 2x127 |
| Cumulative Distribution Function (CDF) | | | | 2x127 |
| NUMBER OF FUNCTIONS AVAILABLE WITHOUT CHANGING MODES OR RERUNNING DATA | 6 | 4 | 20 | 6 |

Footnotes:
[1]1024 data points A vs. B in "NYQ".
[2]Complex data points; 400 real and 400 imaginary, or 400 magnitude and 400 phase, or 400 Nyquist (R vs. I).
[3]Weighting removed and pad-zeros applied in correlation.
[4]Not recommended in 1K mode.

INPUT CHARACTERISTICS (Each Input Channel)

A. Maximum Amplitude - 0.1, 0.2, 0.5, 1, 2, 5, 10, 20 V (0 - peak)

B. Coupling - AC (-3 dB at 0.5 Hz) or DC, normal or digitally inverted, digital ZERO is effective input ground.

C. Impedance - 100 K Ohms

D. Test Signals - 1. Single peak, approximately full scale amplitude, appears in each channel at 64% of analysis range (normal input is disconnected when test signal is on).

2. (Rear Panel) Digitally generated random and digitally filtered random noise outputs provide standard complex functions regardless of frequency range; random sequence over 1,000,000 samples, clocked in sync with input ADC; amplitude 0 - 1V; trigger restarts sequence after pre-sequence of 2048 samples to create pseudo-random noise.

INPUT SAMPLING

12 bit A/D conversion at 2.56 times maximum frequency in the range selected; 256,000 per second maximum external control.

INPUT FILTERS

Range switch automatically selects a pair of matched, low-pass, anti-aliasing filters, which provide at least 70 dB attenuation of those input frequencies which can cause aliasing (10 Hz filter used on 1, 2 and 5 Hz ranges); frequency response ±1.0 dB on 100 kHz range).

TRANSIENT CAPTURE CONTROL

Digital data in input buffer memories held manually by placing the HOLD/RELease button in HOLD (light on), or automatically by triggering on the transient waveform in either A or B input channels at a preset trigger level (±1/2, ±1/4, ±1/8, or ±1/16 FS) after ARM is pushed (light on); anticipation or delay of the trigger set using the keyboard (T->A) from -1 to 63 time windows.

INPUT AMPLITUDE MONITORS

Lights indicate peak levels - OVERLOAD, -6 dB (greater than 1/2 full scale), -12 dB (between 1/2 and 1/4 FS), -18 dB (between 1/4 and 1/8 FS), -24 dB (between 1/8 and 1/16 FS); electronic graticule top and bottom in time display indicates amplitude limits.

## FREQUENCY RANGES

(Any other coverage up to 100 kHz can be set using external sampling at 2.56 x Fmax and calibrated to read correctly using ORDERS; the anti-aliasing low-pass input filters associated with the range switch appear in the signal paths).

| RANGE (Hz) | DUAL 1K MODE* NOMINAL BW (Hz) | TIME WINDOW* (SEC) |
|---|---|---|
| 100K | 250 | .004 |
| 50K | 125 | .008 |
| 20K | 50 | .02 |
| 10K | 25 | .04 |
| 5K | 12.5 | .08 |
| 2K | 5.0 | .2 |
| 1K | 2.5 | .4 |
| 500 | 1.25 | .8 |
| 200 | 0.5 | 2 |
| 100 | 0.25 | 4 |
| 50 | 0.125 | 8 |
| 20 | 0.05 | 20 |
| 10 | 0.025 | 40 |
| 5 | 0.0125 | 80 |
| 2 | 0.005 | 200 |
| 1 | 0.0025 | 400 |

*For CHA 2K mode, nominal BW is X1/2, time window is X2; BW is also lowest frequency that can be read.

STORED FUNCTIONS (Internal Memory)

A. (STO D) - Retains one 800-line spectrum, one 1024-sample time waveform, or two 400 line spectra on display; for cross-spectrum or TF, stores R and I regardless of display.

B. (RCL D) - Displays stored data; reverts back to current data display upon second actuation of pushbutton (LED off).

C. (COMP D) - Displays one stored trace and corresponding current traces if both processed in a similar manner.

D. (EQU D) - Equalizes current transfer function with stored TF (if both processed in a similar manner) by dividing magnitude of current by stored and subtracting phase of stored from current; also equalizes IR and TM.

BUILT-IN ANNOTATED DISPLAY

A. Vertical Display - Linear full scale can be set to 1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, or 8 x $10^k$, or to cursor amplitude, or to other number entered with keyboard; log offset from +300 dB to -300 dB in 10 db steps, display range from 20 dB to 160 dB in 20 dB steps via keyboard (DSPL dB).

B. Time Displays - Self-aligning electronic graticule; input maximum amplitude written on CRT in volts 0 - peak.

C. Frequency Displays - Self-aligning electronic graticule; annotation includes display and scaling as well as input settings and running N of average if recalled.

DISPLAY FORMATS

Time A vs. time B; single or dual channel where applicable; complex spectra magnitude and/or phase, real and/or imaginary, or real vs. imaginary (Nyquist); for frequency, lin/log vertical and horizontal. Overlap of any dual trace except phase/mag.

CALIBRATION AT CURSOR

A. Marker - Single line cursor intensifies each waveform at its intersection to indicate location of measurement; in HARMONIC multiples of cursor frequency are illuminated with multiple dots.

B. Amplitude - E, $E^2$ or dBE (engineering units) using keyboard to establish E at cursor or sensitivity as V/E Reference (R) set for relative measurements; V, $V^2$ (power) or dBV; readings normalized per Hz (such as PSD) using the PER Hz button.

C. Frequency - Hz (cycles/sec.), CPM (cycles/minute), cell number, fraction of FS or orders; reads absolute or as difference from reference frequency.

D. Time - Sec, msec, fraction of FS, cell number or cycles (1/orders).

KEYBOARD SETTINGS (Set and recalled)

AVG N - Number of averages taken (1 - 9999); running N can be displayed.

DLY T->A - Delay (or anticipation) between trigger signal and start of Channel A data window. Set in time windows from -1.000 to +63.000.

DLY A->B - Delay introduced between Channels A and B in time windows 0 to 64.000.

PNL - Stores nine sets of complete panel settings with ID numbers for recall (see below).

CUR LOC - Nine cursor locations stored with ID numbers for recall.

RMS 1-2 - Calculates total RMS power between any two stored cursor locations; cursor alternates between two locations in display.

∫dt, d/t - Effective time-domain integration or differentiation, single or double affects all functions until cleared (e.g. converts acceleration to velocity to displacement).

COH BLANK - sets level of display blanking based on degree of coherence (0 - 1.00).

PLOT RATE - Five X-Y plot speeds from very slow (#1) to very fast (#5).

DISPL dB - 20 dB to 160 dB in 20 dB steps.

LIN - Amplitude at cursor on CHA or CHB set to a linear reference (recall is in V/EU).

dB - Amplitude at cursor on CHA or CHB set to a dB reference (recall is in V/EU).

V/EU - Calibration sensitivity of CHA or CHB set in engineering units.

FREQ REF - Cursor location set in the units of the display, to which all future cursor locations are referenced.

ORDER REF - Cursor location set (in ORD), scaling future cursor locations proportionally (for example, if cursor at .1 FS is assigned "30", then FS will be "300").

DEFINE AUX - Auxiliary codes used for secondary operations.

PANEL STORAGE (PNL) - Stores and recalls nine sets of setup, processing and display settings.

| | |
|---|---|
| CURSOR TYPE | COHERENCE BLANK |
| FREQ READ | PLOT RATE |
| DISPLAY GAIN (offset) | DISPLAY dB |
| AVERAGE MODE | INPUT AMPLITUDE |
| AVERAGE N | ∫dt, d/dt |
| DELAY T->A | AUX CODE |
| DELAY A->B | CAL V/EU (CHA and CHB) |
| MODE | CAPTURE CONTROL |
| FUNCTION | FREQ REF |
| DISPLAY CH | ORDER REF |
| DISPLAY FORMAT | XPND WIDTH* |
| DISPLAY MEMORY | XPND (location)* |

* with -2D Digital Expansion

## NUMERIC CALCULATION

Numbers in entry field, manually entered or transferred from another field can be added, subtracted, multiplied or divided, or the square root or reciprocal taken.

## TEXT ENTRY

Allows 4 lines of 45 alphanumeric characters and punctuation to be entered, edited, and positioned anywhere in the display and plotted, turned on or off selectively and displayed with or without other annotation, graticule, or data.

AVERAGING (9 types)

A. SUM adds N power spectra (N = 1-9999 set with keyboard); redundancy selectable 0% or 50%.

B. DIFF subtracts N power spectra from previous average.

C. EX follows the changing statistics of a signal exponentially with a time constant of (N) x (time window).

D. PEAK produces the profile of the maximum amplitudes at each frequency element during N spectra.

E. SWEEP averages with maximum redundancy.

F. TRANS averages power spectra of N transients automatically in SUM, DIFF, EX or PK modes, except those which overload input; after each capture, the transient trigger is automatically re-armed; used for time averaging.

AVERAGING CONTROL

A. START erases memory and starts averaging.

B. STOP halts averaging.

C. CONT resumes averaging until N is reached; if averaging completed, restarts averaging without erasing memory.

ANALOG OUTPUTS

X, Y and Z outputs for external CRT display; X, Y and pen lift for X-Y plotters; timing pulses for 3-D display (see Model 66-2A); PLOT CAL provides lower-left and upper-right of grid for setup; output of amplitude at cursor.

DIGITAL INTERFACES (Standard Built-In)

A. Full duplex RS232 serial interface with selectable baud rates of 110, 150, 300, 600, 1200, 2400, 4800, 9600; internal programming communicates with digital plotters through the RS232 interface; when used to communicate with external devices, the outputs from the RS232 interface are printable in ASCII characters.

B. IEEE-488-1978 interface (full listener/talker with Service Request capability).

C. High-speed 12-bit A/D converter output interface using 16-bit parallel words (two channels simultaneously); 16-bit digital input to time buffer.

MODEM OPERATION: A simple interconnect cable gives the 660B full compatibility with standard modems and acoustic couplers. The 660B may be controlled and its data received over voice grade telephone lines up to 300 baud. This permits the user to remotely control the 660B and plot the results on a local Model 136A Digital Plotting Adapter.

POWER

425 watts, 600 VA

WEIGHT

36.4 kgm (80 pounds) nominal

SIZE

35.56 cm (14 in.) high, 43.18 cm (17 in.) wide, 52.79 cm (20-7/8 in.) deep.

AVAILABLE OPTIONS

A. DIGITAL ("ZOOM") EXPANSION -2D (Built-In): Expansion by X8 to X512 on 13 ranges from 0 - 10 Hz to 0 - 100 kHz allowing 13 input filter choices; analysis windows from .64 Hz - 12.8 Hz; 47 bandwidths from .8 mHz to 32 Hz.

B. 1/3, 1/1 OCTAVE OPTION -3: One-third or 1/1 octave analysis is performed over 10 octaves either on one channel (CHA 2K mode) or two channels simultaneously (DUAL 1K mode).

C. EXCITATION SOURCE -7: Provides one of three different signal outputs (sinewave output controlled by cursor, bandlimited pseudo-random binary noise, or periodic binary noise) from a 660 which can be used for exciting a test object either mechanically or electrically through a shaker system.

D. CALCULATION OPTION -8: Provides four data manipulation capabilities: Complex Spectrum Math, Time and Frequency Data Editing, Inverse Fourier Transform (IFFT) and Damping Calculation.

E. DIGITAL PLOTTING ADAPTER MODEL 136A: Produces hardcopy (8-1/2 x 11 or 11 x 17 in.) of the display on fanfold paper; paper can be made to automatically advance at end of plot; multi-color plots produced with pen changes between successive displays with controlled data or annotation blanked (AUX codes).

F. DATA RECORDER ADAPTER MODEL 160: Dual mini-floppy disk digital storage of complete functions, annotations, and setup/display settings; search by entered ID number or number "mask", or by sequential file number.

G. STRUCTURAL ANALYSIS SA-2: Extracts modal parameters and displays dynamics of each mode on stored test object geometry. (Structural Analysis and 660B-2D designated as Structural Analysis System 6602A).

H. HAMMER KIT MODEL 52: Hammer with force transducer mounted in its head plus accelerometer for impluse testing.

I. SPECTRUM TRACKING ADAPTER MODEL 24C: Converts tachometer or other input rates to correct sampling rate to display number of orders desired.

J. RECORDING ADAPTER MODEL 61: Polaroid camera with special bezel adapter.

K. 3-D DISPLAY GENERATOR MODEL 66-2A: Time history display of successive traces one under the other stored on companion Tek 613 large-screen storage display.

L. X-Y PLOTTER MODEL 131B: Portable X-Y plotter.

M. TRANSIT CASE MODEL 99L: Roll-around re-useable case for shipment.

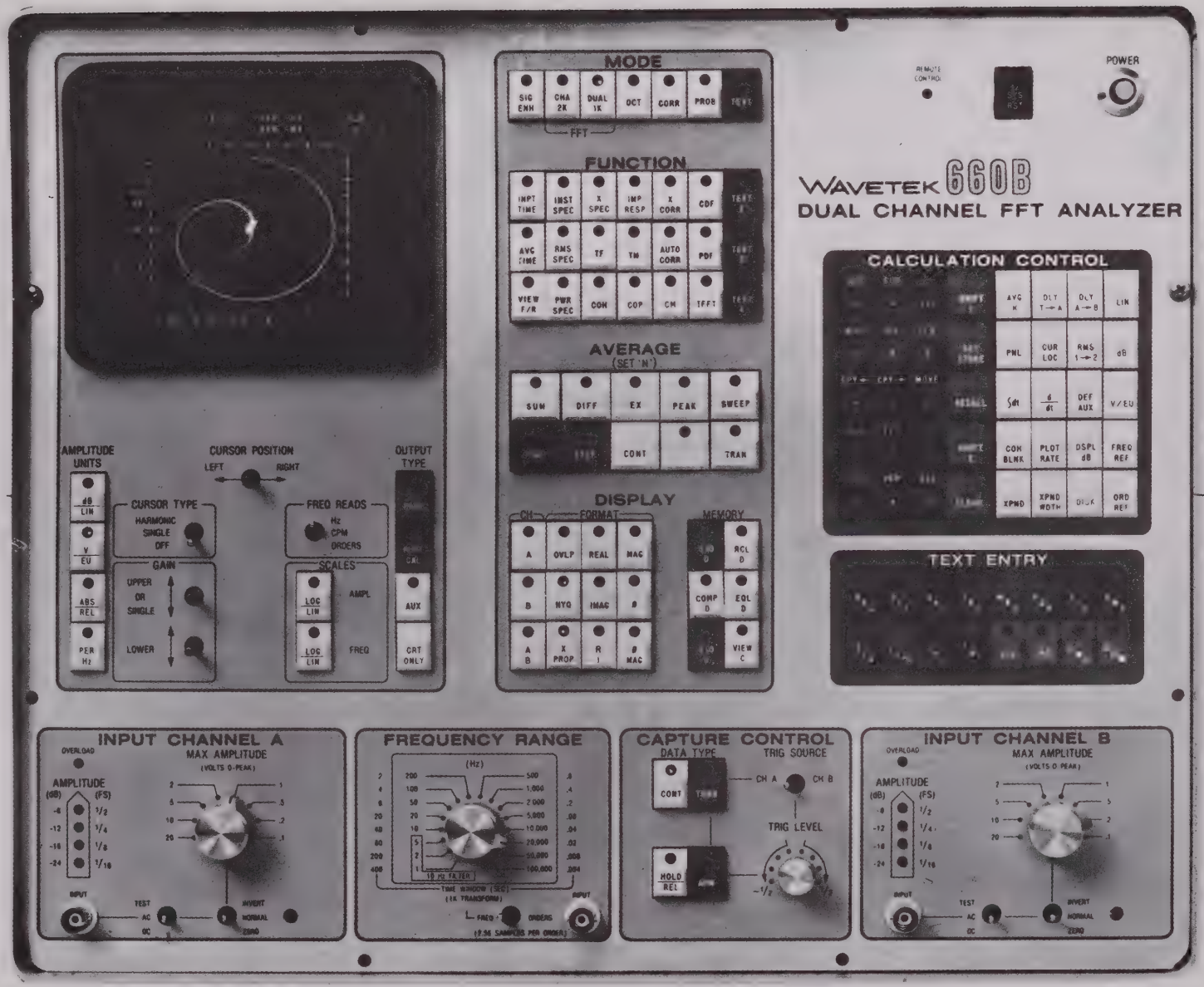



FIGURE 2A. 660B FRONT PANEL.

SECTION 2

# GENERAL CHARACTERISTICS OF THE FRONT PANEL

## 2.0 Characteristics

Figure 2A illustrates the front panel of the Model 660B. Controls are arranged in logical function groups. The majority of front panel controls are momentary contact pushbutton switches. Many of these switches have a light emitting diode (LED) in the center of the pushbutton. An illuminated LED indicates that the particular control is in an on state. Unless a control's LED is illuminated, its function should be assumed to be off. Five of the control pushbuttons (three under AMPLITUDE UNITS and two under SCALES) have a horizontal - on their face. These controls provide either-or (/) choices.

The instrument has a front panel provision to accept two analog data signals and, optionally, an externally generated sample rate. The results of analyses are presented on the built-in cathode ray tube (CRT) located in the upper lefthand corner of the front panel. Additionally, analog and digital signals are provided on the rear panel, Figure 2B, for hard-copy of screen images as well as external digital communication. Table 2-1 gives the characteristics of the rear panel signals.

With line power applied to the rear panel line cord mating receptacle, the instrument may be turned on by depressing the POWER pushbutton in the upper righthand corner of the instrument. When power is initially applied, the instrument wakes up in dual channel processing mode, displaying the instantaneous spectra (with log amplitude vs. linear frequency) of the applied input signals. Depressing the SYS RST pushbutton, adjacent to the POWER switch, will cause the instrument to return to its wake up state. See Section 17.

Turning the power off or initiating a system reset will cause the instrument to clear all stored data. The instrument will retain, however, up to ten previously defined operating states. This storage is restricted to the control settings only.

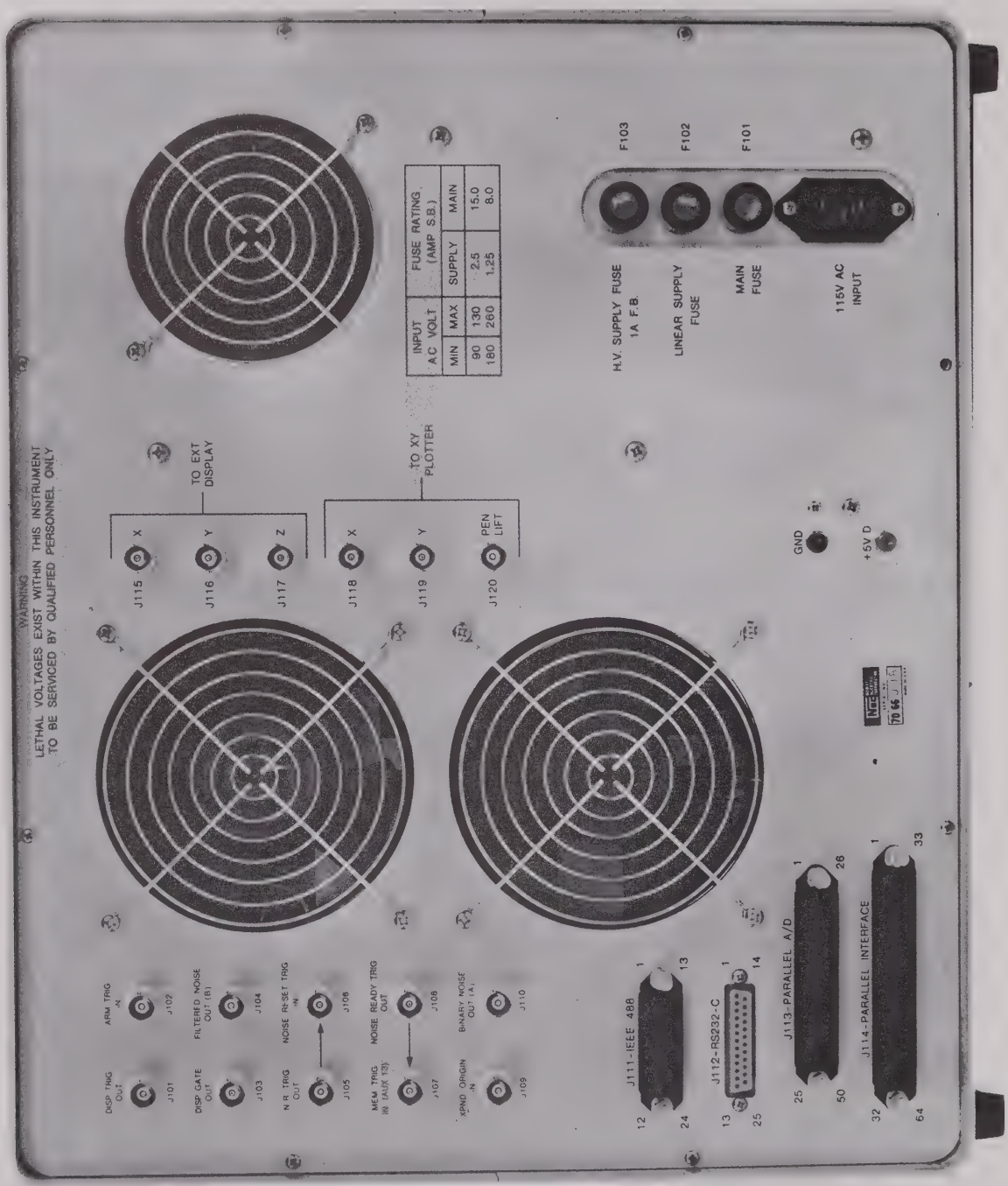



FIGURE 2B. 660B REAR PANEL.

TABLE 2-1

REAR PANEL CONNECTIONS

| CONNECTOR | LABEL | FUNCTION/CHARACTERISTIC |
|---|---|---|
| J101 | DISPlay TRIGger OUT | Low TRUE TTL pulse indicating start of a new display cycle. |
| J102 | SPARE | |
| J103 | DISPlay GATE OUT | High TRUE TTL level indicating data on display distinct from annotation or graticule on display. |
| J104 | FILTERED NOISE OUT | Analog signal used as a test point. Level is 0 to 1 volt peak-to-peak with a notch at approximately 55% of the analyzer range. |
| J105 | Non Redundant TRIGger OUT | Low TRUE TTL pulse indicating start of a new display cycle with new data. |
| J106 | NOISE RESET TRIGger IN | Low TRUE TTL pulse causes the pseudo-random binary noise generation to reset. |
| J107 | MEMory TRIGger IN | With a low TRUE TTL input the 660B will initiate the capture of a buffer of input data. Enabled by DEFine AUXiliary 12 and 13. |

TABLE 2-1 (Con't.)

REAR PANEL CONNECTIONS

| CONNECTOR | LABEL | FUNCTION/CHARACTERISTIC |
|---|---|---|
| J108 | NOISE READY TRIGger OUT | Low TRUE TTL pulse used as input to J107 when a specific repeatable binary sequence is required as a system stimulus. |
| J109 | SPARE | |
| J110 | BINARY NOISE OUT | Analog signal generated by a pseudo-random binary noise generator. This signal has a flat frequency spectrum and is useful as a system stimulus. The signal level is 0 to 1 volt peak-to-peak. |
| J111 | IEEE-488 | Refer to Section 19 |
| J112 | RS232-C | Refer to Section 19 |
| J113 | PARALLEL A/D | Refer to Section 19 |
| J114 | CONTROL INTERFACE | Refer to Section 19 |
| J115 | X TO EXTernal DISPLAY | Analog signal 0 to 1 volts output for external CRT horizontal. |
| J116 | Y TO EXTernal DISPLAY | Analog signal 0 to 1 volts output for external CRT vertical. |
| J117 | Z TO EXTernal DISPLAY | Bi-level output signal for external CRT Z-axis blanking. 0 Volt indicates beam on, -2 Volts indicates beam off. |

TABLE 2-1 (Con't.)

REAR PANEL CONNECTIONS

| CONNECTOR | LABEL | FUNCTION/CHARACTERISTIC |
|---|---|---|
| J118 | X TO XY PLOTTER | Analog output signal for XY plotter horizontal. Signal level 0 to 5 volts. |
| J119 | Y TO XY PLOTTER | Analog output signal for XY plotter vertical. Signal level 0 to 5 volts. |
| J120 | PEN LIFT TO XY PLOTTER | Relay closure. Short for pen down. Open circuit for pen up. |
| TP | TEST | When grounded enables diagnostic monitor. |

SECTION 3

GENERAL CHARACTERISTICS OF THE DISPLAY

## 3.0 Display Characteristics

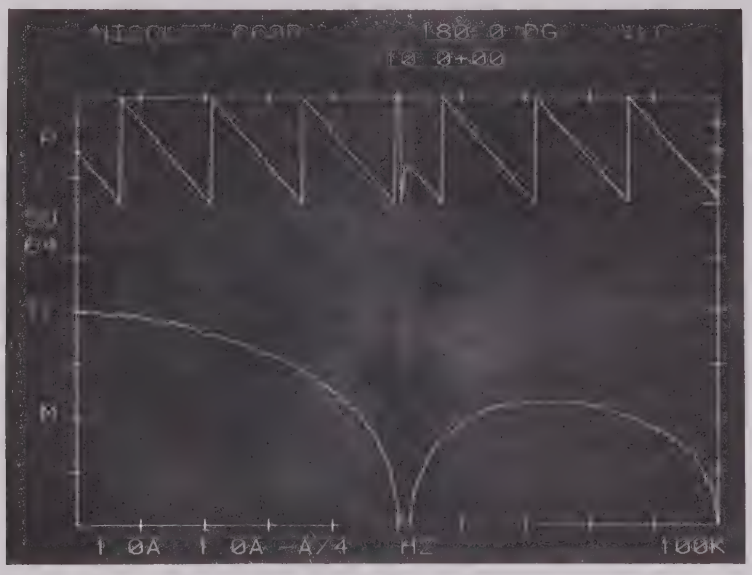



FIGURE 3

Figure 3 illustrates a typical CRT display. The display consists of data reflecting the results of computation as well as an electronically drawn graticule and annotation reflecting the control status of the instrument. Additionally, the CRT serves as a communication interface between the user and the instrument.

The annotation NICOLET 660B appearing in the upper left-hand corner of the display, is in the instrument's entry/recall field. This section of the display is reserved for messages defining the status of the instrument. For example, whenever the instrument is operating in its wake up state, the annotation NICOLET 660B will appear. Three types of information may appear in the entry/recall field:

1. A summary of the most recent transaction conducted through the calculation control group, or

2. A status message informing the user that an operation has been accomplished or informs the user a particular mode of operation is ongoing, or

3. An error message indicating that the user has attempted to perform an operation outside the context of the instrument's repertoire.

Error messages require corrective action on the part of the operator. These messages instruct the operator as to the corrective action that is necessary. Error messages are distinguishable from status messages and calculation control summaries because they are presented in inverted characters. That is, all error messages are presented in dark characters against a white background while normal status messages are presented in light characters against a dark background.

The instrument has the capability to reproduce the CRT display, in its entirety, on the optional Model 134A Digital Plotter and the optional Model 136A Digital Plotting Adapter. This same information may also be recorded using the Model 61 Polaroid Recording Adapter. Additional facility is provided to record the data traces only, on an ordinary analog X-Y plotter. Digital interface capabilities provide for the transmission of the information content, to external digital devices such as the optional Model 160C Data Recorder Adapter.

SECTION 4

OPERATING MODE CONTROL GROUP

## 4.0 Operating MODE

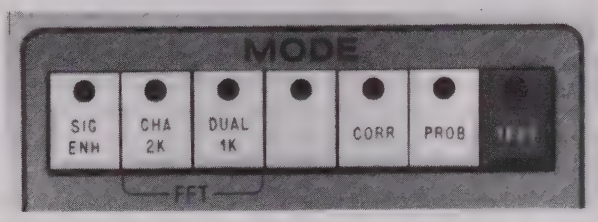



FIGURE 4

Figure 4 illustrates the operating mode control group located in the top central portion of the front panel. One of five operating modes may be selected by depressing the appropriate pushbutton control. The selected mode of operation is indicated by its associated LED. Selection of an operating mode determines what functions of the input data are computed.

Reading from left to right, the five operating modes are:

1. SIG ENH, Signal enhancement; providing dual channel, 1024 point resolution, time domain analysis.

2. CHA 2K, Channel A Fast Fourier Transform; providing single channel, data from channel A, time and frequency domain analyses. Frequency functions are provided with a resolution of 800 points while time domain functions are provided with a resolution of 2048 (2K) points.

3. Dual 1K, 1K Channel AB Dual Fast Fourier Transform; providing dual channel processing in the time and frequency domains. Frequency domain functions are presented with a resolution of 400 points while time domain functions are presented with a resolution of 1024 (1K) points.

4. OCT, Octave; available as an option, computes 1/1 or 1/3 octave, A-weighting or normal, in 1K or 2K FFT MODE.

5. CORR, Correlation; providing the same general characteristics as the preceding mode with parameters optimized for auto and cross correlation functions.

6. PROB, Probability; providing dual channel analysis in time and amplitude domains. Amplitude domain functions are presented with a resolution of 127 points while time domain functions are presented with a resolution of 1024 points.

The functions available in each mode are summarized in Table 4-1. Note that correlation functions are available in the 1K Dual Channel Fast Fourier Transform mode but that certain processing parameters may not be optimized for these functions. Conversely, in the correlation mode, all of the 1K Dual Channel FFT functions are also available. In the correlation mode these functions will be compromised. Hence, correlation mode should be selected if correlation functions are of fundamental interest; 1K Dual Channel FFT mode should be selected for all other cross property functions.

In the wake up state the instrument automatically selects the 1K Dual Channel AB FFT mode.

TABLE 4-1
AVAILABLE FUNCTIONS BY MODE

| FUNCTION | MODE | | | | |
|---|---|---|---|---|---|
| | SIGNAL ENHANCEMENT | 2K FFT (CH A ONLY) | 1K FFT (A, B DUAL) | CORRELATION | PROBABILITY |
| Input Time History | A & B | A | A & B | A & B | A & B |
| Averaged Time History | A & B | | | | |
| Impulse Response | | | ✓ | NR | |
| Instant Spectrum | (1) | A | A & B | NR | |
| RMS Spectrum | | A | A & B | NR | |
| Power Spectrum | | A | A & B | NR | |
| Coherent Output Power Spectrum | | | ✓ | NR | |
| Cross Spectrum | | | ✓ | NR | |
| Transfer Function | | | ✓ | NR | |
| Transmissibility Function | | | ✓ | NR | |
| Coherence Function | | | ✓ | NR | |
| Auto Correlation Function | | | NR | ✓ | |

(Continued)

A Single Channel Function Available for Channel A Only.
A & B Single Channel Function Available for Channels A and B.
✓ Cross Property Function Available and Optimized.
NR Cross Property Function Available but Not Recommended.
(1) In this mode only, it provides instant spectra of averaged time histories for both A and B channels.
(2) Complex Math and IFFT are available with special calculation Option -8. (IFFT is only valid for data stored in the complex buffer C.

TABLE 4-1
AVAILABLE FUNCTIONS BY MODE (CON'T.)

| FUNCTION | MODE | | | | |
|---|---|---|---|---|---|
| | SIGNAL ENHANCEMENT | 2K FFT (CH A ONLY) | 1K FFT (A, B DUAL) | CORRELATION | PROBABILITY |
| Cross Correlation Function | | | NR | ✓ | |
| Complex Math | CM(2) | | CM(2) | | |
| Inverse FFT | IFFT | | IFFT | | |
| Probability Density Function | | | | | A & B |
| Cumulative Distribution Function | | | | | A & B |

| | |
|---|---|
| A | Single Channel Function Available for Channel A Only. |
| A & B | Single Channel Function Available for Channels A and B. |
| ✓ | Cross Property Function Available and Optimized. |
| NR | Cross Property Function Available but Not Recommended. |
| (1) | In this mode only, it provides instant spectra of averaged time histories for both A and B channels. |
| (2) | Complex Math and IFFT are available with special calculation Option -8. (IFFT is only valid for data stored in the complex buffer C. |

SECTION 5

FREQUENCY RANGE CONTROLS

## 5.0 FREQUENCY RANGE Controls

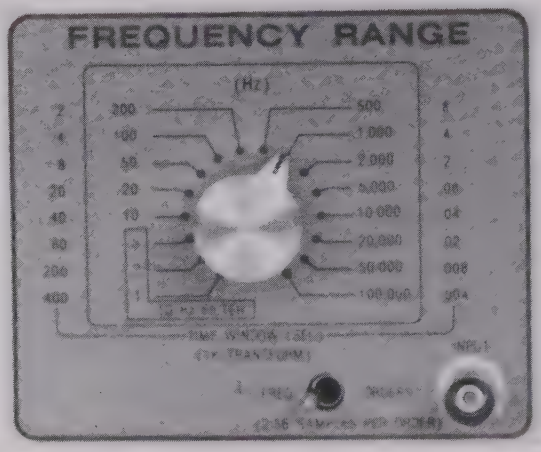



FIGURE 5A

Figure 5A illustrates the frequency range control group located in the lower central portion of the front panel. Sixteen frequency ranges between 1 Hz and 100 kHz full scale may be selected in a 1, 2, 5 progression. The selected frequency range is the maximum frequency analyzed in FFT processing modes. The outer annotation surrounding the frequency range switch specifies the duration of the memory load period in seconds associated with a single 1024 point transform. The memory load period in 2K FFT mode is twice this duration.

The setting of the frequency range switch determines the sample rate at which the data is acquired, for internal sampling, and the bandwidth of the anti-aliasing filters preceding the instrument's analog-to-digital converters. Note that selecting the 1, 2, or 5 Hz range activates the instrument's 10 Hz anti-aliasing filter. When operating on these frequency ranges, external anti-aliasing filters should be provided.

The internal sample rate provided by the analyzer is always equal to 2.56 times the selected frequency range. The internal sample rate is provided automatically when the FREQ/ORDERS switch is in the FREQ position. Placing this switch in the ORDERS position allows the instrument to operate with an external sample rate. The external sample rate is applied through the front panel INPUT BNC connector. When operating with an external sample rate, the maximum frequency analyzed is equal to the sample rate divided by 2.56. The external sample rate does not have to be constant in frequency. This facility is particularly useful in the analysis of rotating machineries.

SECTION 6

INPUT CHANNEL A AND INPUT CHANNEL B CONTROL GROUPS

## 6.0 INPUT Control Groups

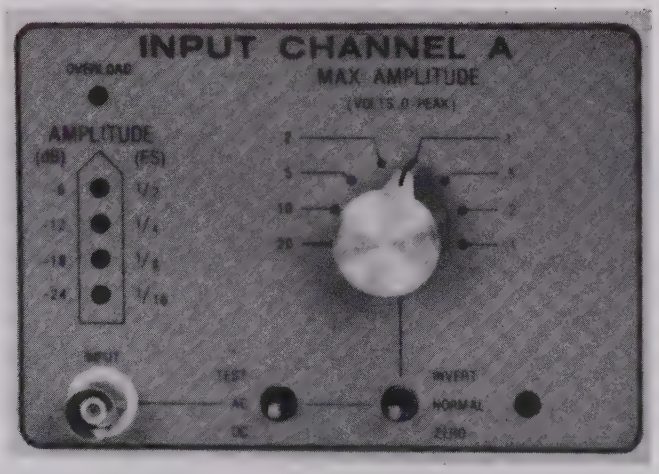



FIGURE 6A

Figure 6A illustrates one of two identical input control groups located in the lower corners of the front panel. The data signal to be analyzed is applied to the input BNC connector. AC or DC coupling may be selected, or a test signal may be substituted for the input. When AC coupling is selected, the 3 dB point is located at less than 1 Hz. When the test signal is selected, a periodic signal at 64% of the selected analysis range is applied. When the zoom is activated the test signal appears at 65.5% of the baseband display.

The signal may be analyzed as applied (normal) or it may be inverted. Inverting the signal changes the sign of its amplitude. Alternatively, an input ZERO may be selected. Selecting an input ZERO provides a digital zero code output from the analog-to-digital converter but does not affect the electrical characteristics of the input BNC.

The MAX AMPLITUDE selector provides eight choices of input sensitivity from .1 volt to 20 volts (0-PEAK) in a 1, 2, 5 progression. Proper setting of the MAX AMPLITUDE control is achieved by viewing the AMPLITUDE LEDs. Proper setting of the MAX AMPLITUDE control is achieved when the OVERLOAD LED is off and as many of the remaining LEDs as possible (signal dependent) are on.

Settings of the input controls are annotated on the CRT image as shown in Figure 6B. These annotations always appear in the lower lefthand corner of the display. Annotation for channel A (left channel) appears on the left side. Annotation for channel B appears on the right side. If the signal has been inverted a minus sign is displayed. The selected MAX AMPLITUDE voltage is displayed. This number reads 0.0 if a digital "0" has been applied. AC coupling is indicated by the letter A, DC coupling by the letter D, and the test signal by the letter T.

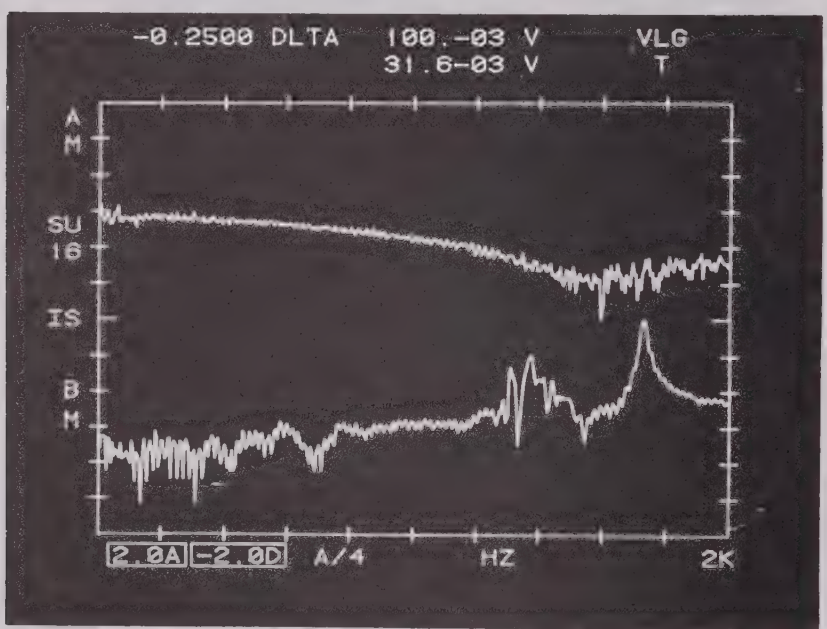



FIGURE 6B

SECTION 7

CAPTURE CONTROLS

## 7.0 CAPTURE CONTROL Group

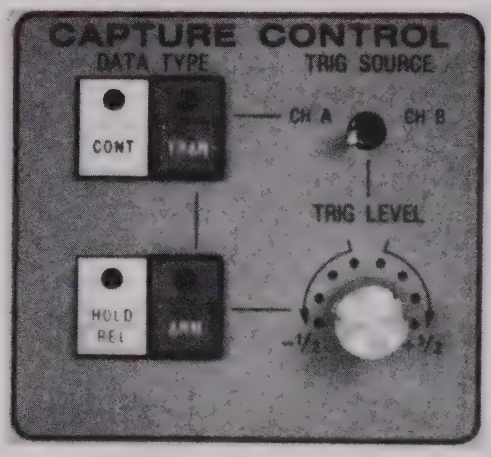



FIGURE 7A

Figure 7A illustrates the capture control group located in the lower central portion of the front panel. The DATA TYPE controls allow selection of processing of continuous or transient signals. When the CONT button is depressed, a Hanning squared, cosine$^4$, window is applied to the data. When the TRAN button is depressed, the data is analyzed using a uniform window. Hence, the data may be weighted or unweighted.

Note that entering or exiting the transient mode of averaging causes the automatic selection of unweighted data type or weighted data type. The automatic selection may be overridden manually.

The instrument may be caused to hold its current input data window by depressing the manual HOLD/REL button. When this button is depressed, its associated LED lights indicating the hold state. Depressing the button a second time causes the data to be RELeased. This button permits freezing portions of the input signals for further examination.

Alternatively, the instrument may be programmed to automatically go into hold. This is accomplished by selecting either channel A or channel B to be the trigger source. The signal level which causes the hold state may be selected using the TRIG LEVEL rotary switch. This selector permits levels from $\pm$ 1/16 to $\pm$ 1/2 of the selected MAX AMPLITUDE to be chosen.

Depressing the ARM button, causing its LED to light, arms the analyzer to anticipate the transient capture conditions. When these conditions are met, the system automatically goes into a hold state.

Figure 7B illustrates the display annotation reflecting the status of the capture controls. The circled T indicates that the transient data type has been selected. Continuous data type is indicated with a C. When operating in correlation mode a special window is provided regardless of the settings of the data type controls. This window is uniform over the first half of the time window and zero over the second half of the time window. The correlation window is indicated by the annotation ZC for zeroed correlation window.

Annotation below the display indicates the status of the TRIG SOURCE and TRIG LEVEL controls. Absence of a sign is a positive trigger level. A minus sign is used for negative levels. The letter A or B indicates which channel is the trigger source. The suffix, / 4, indicates the trigger level is 1/4 of the selected maximum amplitude.

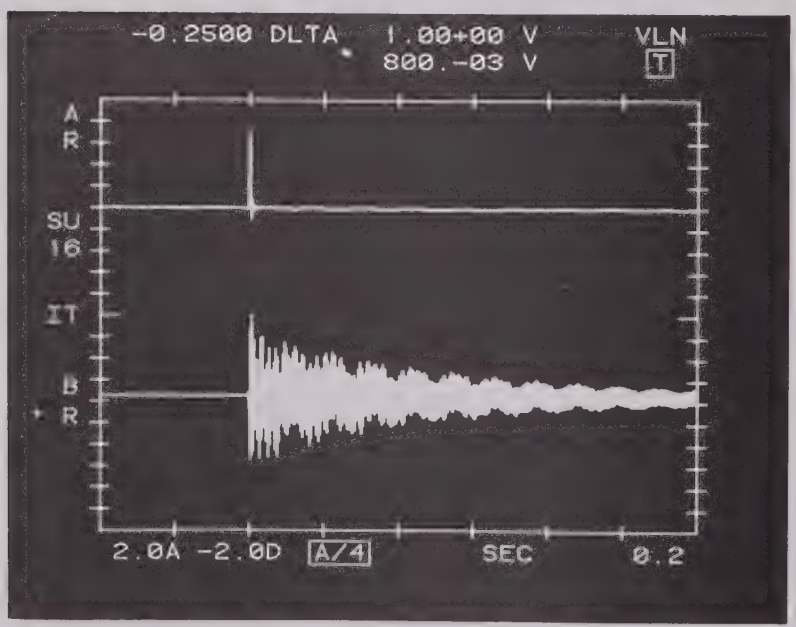



FIGURE 7B

SECTION 8

AVERAGING CONTROL GROUP

## 8.0 AVERAGE Control Group

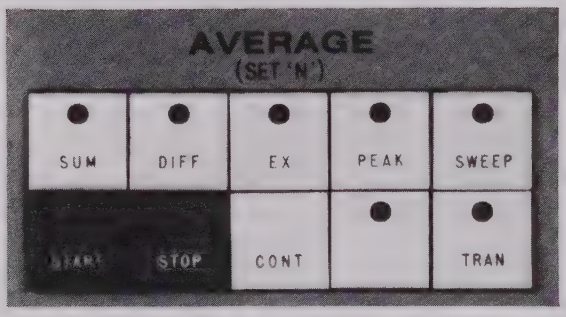



FIGURE 8A

Figure 8A illustrates the averaging control group. One of nine averaging modes may be selected. These are:

1. SUM, Summation
2. DIFF, Difference
3. EX, Exponential
4. PEAK, Peak
5. SWEEP, Sweep
6. TRAN SUM, Transient Summation
7. TRAN DIFF, Transient Difference
8. TRAN EX, Transient Exponential
9. TRAN PEAK, Transient Peak

When operating in signal enhancement, the instrument performs ensemble averaging for channel A and B data in the time domain. When operating in the 2K Single Channel FFT mode the instrument performs ensemble averaging of the power spectra of data applied to channel A. When operating in either the 1K Dual Channel FFT or the correlation modes, the instrument performs ensemble averaging of the power spectra for both channel A and B as well as ensemble averaging of the real and imaginary components of the cross spectrum between channels A and B. When operating in the probability mode, the instrument performs accumulation of occurrence and amplitude of the data applied to both channels A and B.

When summation averaging is selected, the averager section performs summation averaging over N preset spectra or time windows. The number N is entered through the calculation control group discussed in Section 16. In summation averaging, each constituent in the average is weighted equally. When averaged functions are displayed, their amplitude is continuously normalized based upon the number of constituents currently averaged. Summation averaging may be conducted on statistically independent time windows, nonredundant data, or upon sequential time records that overlap by no more than 50% (50% redundancy). Averaging redundancy is determined by entry through the calculation control group.

Difference averaging is very similar to summation averaging except that each constituent is subtracted, rather than added, from the average. Difference averaging is performed following a summation average to subtract noise background from experimental measurements. Therefore, starting the averager in the DIFF mode does not clear the averager buffers.

Exponential averaging is a moving average in time. In this mode of averaging, the most recent information is weighted heavily while the oldest history is weighted lightly. The weighting function between these extremes is time exponential, hence, the name. Exponential averaging is equivalent to placing a resistor-capacitor (RC) filter or leaky integrator on each point in the spectrum.

Peak averaging is not truly an average. It provides a one time statistic. In peak averaging, the largest event that occurs at any frequency or time position is stored in the averager memory. Peak averaging provides the "worst case" spectrum or time record. When peak averaging is selected, every spectrum computed by the 660B is tested to see if the value within it has exceeded a previously stored value. This processing is, therefore, performed at maximum redundancy.

Sweep averaging is specifically designed for the analysis of systems excited by swept sine. Sweep averaging is summation averaging conducted at maximum redundancy. That is, summation averaging is performed at the maximum 660B spectrum computation rate, rather than waiting for the required redundancy conditions.

Transient averaging is a special mode of averaging optimized for the analysis of transient signals. When a transient averaging mode is entered, TRANS data type is selected automatically. Exiting the transient averaging mode automatically sets the data type to CONT (refer to Section 7). During transient averaging the instrument automatically re-arms

itself after each transient acquisition. If an acquired transient caused an overload of the instrument's analog-to-digital converters, it is not averaged. The instrument only averages spectra or time histories resulting from transient inputs that satisfied the trigger conditions but did not overload the input of the instrument. This averaging mode is particularly useful when examining structures using impulsive techniques as discussed in the Application Notes. The transient mode is available when using summation, difference, exponential or peak averaging.

An averaging process is initiated by depressing the START pushbutton. The LED on the START button remains lighted while averaging is being conducted. At the conclusion of the averaging period, this LED turns off. Depressing the START button erases any previously averaged data (except DIFFerence mode) and starts the averaging count from one.

Summation and difference averaging are conducted until the preset averager N is reached. The process may be manually stopped or interrupted by depressing the STOP pushbutton. Exponential, peak and sweep "averaging" all continue until stop is depressed. To resume the averaging process, depress the CONT, continue, pushbutton. Depressing the CONT pushbutton does not erase prior information nor does it reset the averaging counter. The CONT pushbutton may be used to average data in excess of the preset N without incurring any scaling errors.

In exponential averaging, averager N determines the rate of the exponential decay. If AVGN = 1, new data replaces old data after each pass of the averager.

Figure 8B illustrates CRT annotation describing the status of the averaging process. The present averaging conditions are specified by a 2 or 3 letter code for averaging mode directly above the preset averager N, i.e., SU 100 shown here. The averaging codes are:

1. SU for Summation
2. DF for Difference
3. EX for Exponential
4. PK for Peak
5. SW for Sweep
6. TSU for Transient Summation
7. TDF for Transient Difference
8. TEX for Transient Exponential
9. TPK for Transient Peak

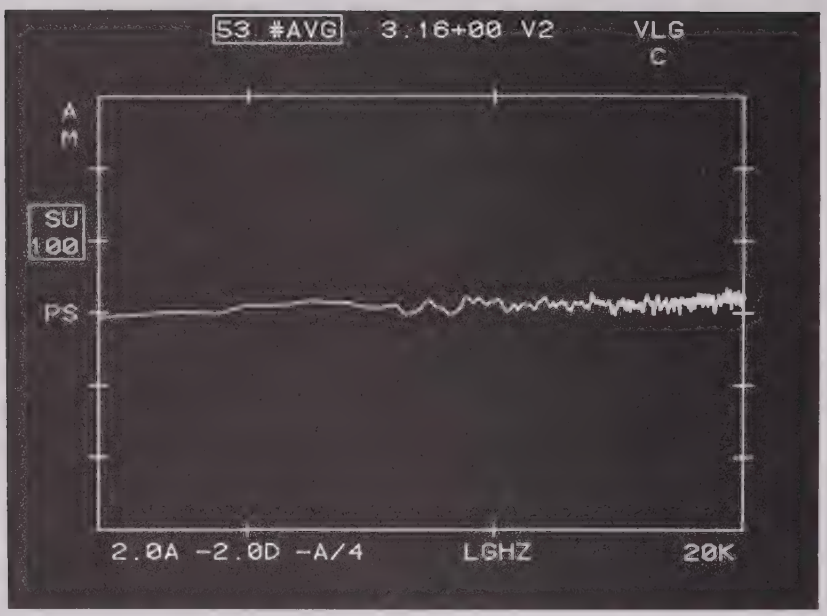



FIGURE 8B

Also, the calculation control group permits displaying the running averager count (RECALL AVG N) as the process proceeds. The annotation 53 # AVG, shown here indicates that 53 of the preset 100 averages have been acquired at this instant in time. Table 8-1 summarizes the system's averaging modes. Table 8-2 summarizes the mathematical operations performed in the various averaging modes.

In the wake up state the averager is preset to summation averaging mode with N equal to 16.

TABLE 8-1

VALID AVERAGING MODES

| AVG MODE | OPERATING MODE | | | | |
|---|---|---|---|---|---|
| | SIG ENH | CHA 2K | DUAL 1K | CORR | PROB |
| 1. SUMMATION | X | X | X | X | X |
| 2. DIFFERENCE | X | X | X | X | |
| 3. EXPONENTIAL | X | X | X | X | |
| 4. PEAK | | X | X | X | |
| 5. SWEEP | | X | X | X | |
| 6. TRANSIENT SUMMATION | X | X | X | X | X |
| 7. TRANSIENT DIFFERENCE | X | X | X | X | |
| 8. TRANSIENT EXPONENTIAL | X | X | X | X | |
| 9. TRANSIENT PEAK | | X | X | X | |

TABLE 8-2

AVERAGING OPERATIONS

| Type of Averaging | Operation Performed |
|---|---|
| Summation<br>SU<br>TSU<br>SWEEP | $G_{k+1} = G_k + S_{k+1}$ $0 \leq k$ N<br>$0 \leq k \leq \infty$ for sweep<br>$P_{i(k+1)} = P_{i(k)}$ for $A_{i(k+1)}(t) \neq v_i$<br>$= P_{i(k)+1}$ for $A_{i(k+1)}(t) = v_i$ |
| Difference<br>DF<br>TDF | $G_{k+1} = G_k - S_{k+1}$ $0 \leq k \leq N$ |
| Exponential<br>EX<br>TEX | $G_{k+1} = \frac{S_{k+1} - G_k}{2\exp(N^*)}$ $G_k$ $0 \leq k \leq \infty$<br>$N^* = \text{Integer}(\log_2 N)$ |
| Peak<br>PK<br>TPK | $G_{k+1} = \max\{S_{i(k+1)}, G_{ik}\}$ for all i<br>$0 \leq k \leq \infty$ |

Notation:

| | | |
|---|---|---|
| P | = | Probability value |
| A(t) | = | Input time waveform |
| G | = | Current averaged spectrum or spectra |
| S | = | Instantaneous spectrum |
| k | = | Number of averages completed |
| N | = | Number of averages set via Calculation Control Keyboard. Wake up value = 16 |
| i | = | Particular cell in spectrum mode or bin in probability mode |
| $v_i$ | = | Voltage range associated with bin i |

SECTION 9

FUNCTION CONTROL GROUP

## 9.0 FUNCTION Control Group

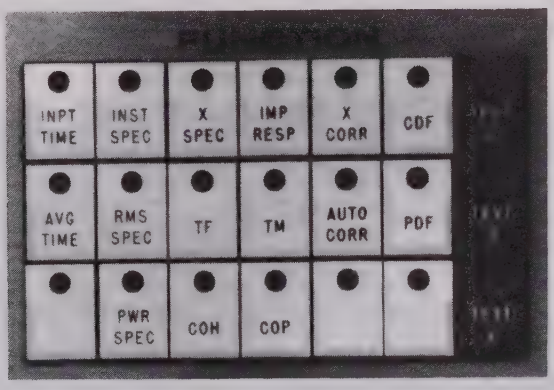



FIGURE 9A

Figure 9A illustrates the function control group. Depressing a button in this group causes the display of a selected function. If the selected function is not available in the selected operating mode, the error message FUNCTION N/A, for function not available, will be seen in the entry/recall field. Functions available by mode are listed in Table 4-1.

The functions, CM and IFFT, control features of the Spectrum Calculation Option -8. Information for these features is contained in the options section of this manual, Chapter 21.

All functions with the exception of INPT TIME, input time histories, and INST SPEC, instantaneous spectra, require averaging for their computation. Hence, the averaging process must be started before meaningful displays of most functions will be obtained. Any function may be viewed while the averaging is in process.

The selected function is denoted on the CRT display by a function label. In Figure 9B, the annotation PS indicates that a power spectrum is being displayed.

Table 9-1 summarizes the available functions, their front panel abbreviations in the function control group, their CRT function labels, and modifications to these labels indicating the effects of controls described in Sections 12 and 15. Table 9-2 gives the mathematical definitions of the available functions.

In the wake up state, instantaneous spectrum is the selected function.

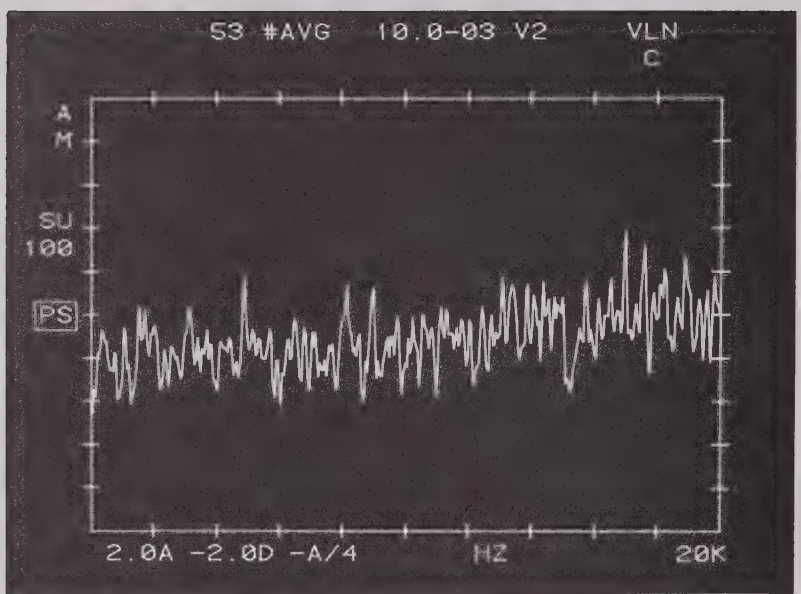



FIGURE 9B

TABLE 9-1

FUNCTION LABELS

| FUNCTION | PANEL ABBREVIATION | CRT LABEL | MODIFIED LABEL* | AVERAGING REQUIRED | DATA TYPE |
|---|---|---|---|---|---|
| INPUT TIME HISTORY | INPUT TIME | IT | - | NO | REAL |
| AVERAGED TIME HISTORY | AVG TIME | AT | - | YES | REAL |
| AVERAGED TIME SPECTRUM | INST SPEC | ATS | ATD | YES | COMPLEX |
| IMPULSE RESPONSE | IMP RESP | IR | EIR | YES | REAL |
| INSTANT SPECTRUM | INST SPEC | IS | ISD | NO | COMPLEX |
| RMS SPECTRUM | RMS SPEC | RS | RSD | YES | MAGNITUDE |
| POWER SPECTRUM | PWR SPC | PS | PSD | YES | MAGNITUDE |
| COHERENT OUTPUT POWER SPECTRUM | COP | CP | CPD | YES | MAGNITUDE |
| CROSS SPECTRUM | X SPEC | CS | CSD | YES | COMPLEX |
| TRANSFER FUNCTION | TF | TF | ETF | YES | COMPLEX |
| TRANSMISSIBILITY FUNCTION | TM | TM | ETM | YES | MAGNITUDE |
| COHERENCE FUNCTION | COH | COH | - | YES | REAL |
| AUTO CORRELATION FUNCTION | AUTO CORR | ACF | - | YES | REAL |
| CROSS CORRELATION FUNCTION | X CORR | CCF | - | YES | REAL |
| PROBABILITY DENSITY FUNCTION | PDF | PDF | - | YES | REAL |
| CUMULATIVE DISTRIBUTION FUNCTION | CDF | CDF | - | YES | REAL |

*E Prefix Denotes Equalization, i.e. Equalized Impulse Response = EIR
D Suffix Denotes Density (per Hz) Normalization, i.e. Power Spectral Density = PSD

TABLE 9-2

DEFINITIONS OF FUNCTIONS

| DISPLAY SELECT | FUNCTIONS COMPUTED | DESCRIPTION |
|---|---|---|
| TIME (Δ)<br>(Inpt. Time-IT) | $A(t)$ | Digital time history of input signal. (Display shows actual data processed.) |
| Instant FFT (Δ)<br>(Inst. Spec.-IS) | $S_A = \mathcal{F}\{A(t)\}$<br>$= \lvert S_A\rvert\cos(\phi_A) - j\lvert S_A\rvert\sin(\phi_A)$ | Complex spectrum of time history, A(t). Magnitude $\lvert S_A\rvert$ defines instantaneous spectral content. Phase angle, $\phi_A$, describes relative phasing of periodic harmonic components. Absolute angles are only meaningful if analysis window is synchronized to periodic harmonic data. |
| LIN | $\lvert S_A\rvert$ | |
| LOG | $20\text{LOG}_{10}\lvert S_A\rvert$ | |
| PHASE | $\phi_A$ | |
| REAL | $\lvert S_A\rvert\cos\phi_A$ | |
| IMAG | $\lvert S_A\rvert\sin\phi_A$ | |
| Aver.Spec. (Δ)<br>(Pwr. Spec.-PS) | $G_{AA} = \overline{S_A \cdot S_A}^*$<br>$= \overline{S_A^2}$ | Ensemble average of squared spectrum magnitude (formed by multiplying complex spectrum by its conjugate). A real (rather than complex) spectrum, defining average power at each frequency. |
| LIN | $G_{AA}$ | |
| LOG | $10\text{LOG}_{10}G_{AA}$ | |
| (RMS Spec.-RS) | $\sqrt{G_{AA}}$ | |
| Aver. Cross Spec<br>(X Spec.-CS) | $G_{AB} = \overline{S_B \cdot S_A}^*$<br>$= \lvert\overline{S_A \| S_B \cos(\phi_B - \phi_A)}\rvert +$<br>$j\lvert\overline{S_A \| S_B \sin(\phi_B - \phi_A)}\rvert$ | Ensemble averaged complex product of spectrum, $S_A^*$. Indicates those frequencies where both A(t) and B(t) have content. Phase angles indicate average phase difference between signals at each frequency. |
| LIN MAG | $\lvert G_{AB}\rvert$ | |
| LOG MAG | $10\text{LOG}_{10}\lvert G_{AB}\rvert$ | |
| PHASE | $\overline{\phi_B - \varphi_A}$ | |
| REAL | $\lvert\overline{G_{AB}\cos(\phi_B - \phi_A)}\rvert$ | |
| IMAG | $\lvert\overline{G_{AB}\sin(\phi_B - \phi_A)}\rvert$ | |

TABLE 9-2

DEFINITIONS OF FUNCTIONS (CONT.)

| DISPLAY SELECT | FUNCTIONS COMPUTED | DESCRIPTION |
|---|---|---|
| Transfer Function (TF) | $H_{AB} = \frac{G_{AB}}{G_{AA}} = \frac{S_B \cdot S_A^*}{S_A \cdot S_A^*}$ $= \frac{\overline{\lvert G_{AB} \rvert \cos(\phi_B - \phi_A)}}{\overline{\lvert G_{AA} \rvert}} + j \frac{\overline{\lvert G_{AB} \rvert \sin(\phi_B - \phi_A)}}{\overline{\lvert G_{AA} \rvert}}$ | Complex ratio of cross spectrum, $G_{AB}$, to input power spectrum, $G_{AA}$, defines the gain and phase lag introduced by a transmission system excited by A(t) and responding with B(t). |
| LIN MAG | $\lvert H_{AB} \rvert$ | |
| LOG MAG | $20\text{LOG}_{10} \lvert H_{AB} \rvert$ | |
| PHASE | $\overline{\phi_B - \phi_A}$ | |
| REAL | $\overline{\lvert H_{AB} \rvert \cos(\phi_B - \phi_A)}$ | |
| IMAG | $\overline{\lvert H_{AB} \rvert \sin(\phi_B - \phi_A)}$ | |
| Transmissibility | $H'_{AB} = \frac{G_{BB}}{G_{AA}} = \frac{S_B \cdot S_B^*}{S_A \cdot S_A^*}$ | Real ratio of output power spectrum to input power spectrum. |
| LIN | $\lvert H'_{AB} \rvert$ | |
| LOG | $20\text{LOG}_{10} \lvert H'_{AB} \rvert$ | |
| Impulse Response (Imp. Resp.-IR) | $IR = \mathcal{F}^{-1}\{H_{AB}\}$ | Impulse response of the system assuming input A(t) and response B(t). |

TABLE 9-2

DEFINITIONS OF FUNCTIONS (CONT.)

| DISPLAY SELECT | FUNCTION COMPUTED | DESCRIPTION |
|---|---|---|
| Coherent Output Power (COP) | $COP = \frac{G_{AB} \cdot G_{AB}^*}{G_{AA}}$ $= \gamma^2_{AB} G_{BB}$ | Coherent output power (COP) spectrum indicates power in signal, B(t), that is coherent with signal, A(t). Total power spectrum $G_{BB}$, indicates entire content of B(t) while COP indicates only that portion caused by A(t) thru a linear process. When B(t) is caused by unrelated multiple inputs, COP indicates only that portion due to single input, A(t). |
| LOG | $10 \log_{10} COP$ | |
| Coherence (COH) | $\gamma^2_{AB} = \frac{G_{AB} \cdot G_{AB}^*}{G_{AA} \cdot G_{BB}}$ $= \frac{\lvert G_{AB} \rvert^2}{G_{AA} \cdot G_{BB}}$ | Real Spectrum "power squared" ratio indicates linear cause/effect relationship between A(t) and B(t). Linear transmission system excited only by A(t) yields $\gamma_{AB}^2 = 1$ at all frequencies. Nonlinearities or inputs in addition to A(t) produce $\gamma_{AB}^2$ between "0" and "1". |
| Auto-Correlation Function ($\Delta$) (Auto Corr.-ACF) | $R_{AA}(\tau) = \mathbb{F}^{-1}\{G_{AA}\}$ $= \frac{1}{p} \int_0^p A(t) \cdot A(t + \tau) dt$ | Time domain statistic comparing similarity of A(t) to replicates of itself, delayed by time, $\tau$. At $\tau = 0$, $R_{AA}$ = mean square of A(t). As $\tau \to \infty$, $R_{AA}$ approaches square of mean value. Oscillations in $R_{AA}$ indicate bandwidth and periodicity of A(t). |

TABLE 9-2

DEFINITIONS OF FUNCTIONS (CONT.)

| DISPLAY SELECT | FUNCTIONS COMPUTED | DESCRIPTION |
|---|---|---|
| Cross - Correlation Function (X Corr.-CCF) | $R_{AB}(\tau) = \mathcal{F}^{-1}\{G_{AB}\}$ $= \frac{1}{p}\int_0^{\rho} A(t)B(t+\tau)dt$ | Time statistic comparing similarity of A(t) and B(t). Value of $\tau$ that maximizes $R_{AB}$ indicates time lag between signals. Maximum value of $R_{AB}$ divided by the square root of $[R_{AA}(0)]$ $[R_{BB}(0)]$ yields correlation coefficient (equal to 1 for identical signals, 0 for unrelated signals). |
| Signal Enhancement ($\Delta$) (Avg.Time - AT) | $\overline{A}(t)$ | Ensemble averaged time histories computed at each time point across a series of instantaneous time histories, each triggered from a common condition. Used to extract mean value time history. |
| Linear Spectrum ($\Delta$) (Inst. Spec.-IS) | $S_{\overline{A}} = \mathcal{F}\{A(t)\}$ $= \lvert S_{\overline{A}}\rvert\cos(\phi_{\overline{A}}) + j\lvert S_{\overline{A}}\rvert\sin(\phi_{\overline{A}})$ | Complex spectrum of of the average time data. Magnitude $\lvert S_A\rvert$ defines the spectral content. Phase angle $\phi_A$ describes relative phasing of periodic harmonic components. Absolute angles are only meaningful if analysis windows were synchronized to periodic harmonic data. |
| LIN MAG | $\lvert S_A\rvert$ | |
| LOG MAG | $20\text{LOG}_{10}\lvert S_A\rvert$ | |
| PHASE | $\phi_{\overline{A}}$ | |
| REAL | $\lvert S_{\overline{A}}\rvert\cos\phi_{\overline{A}}$ | |
| IMAG | $\lvert S_{\overline{A}}\rvert\sin\phi_{\overline{A}}$ | |

TABLE 9-2

DEFINITIONS OF FUNCTIONS (CONT.)

| DISPLAY SELECT | FUNCTION COMPUTED | DESCRIPTION |
|---|---|---|
| Probability Density Function (PDF) | $q(x) = \frac{d[Q(x)]}{dx}$ such that $\int_a^b q(x)dx = P = \{a<A\leq b\}$ | Statistic defining most probable amplitude of A(t). |
| Cumulative Distribution Function (CDF) | $Q(x) = P\{A\leq x\} = \int_0^x q(x)$ | Statistic defining probability that time signal A(t) has instantaneous amplitude of x or less. |

Definition of Symbols

| | | |
|---|---|---|
| A(t) | - | Input time function on Channel A |
| B(t) | - | Input time function on Channel B |
| $\lvert S\rvert$ | = | Magnitude of instant FFT = $\sqrt{S^2_{REAL} + S^2_{IMAG}}$ |
| $\phi$ | = | Phase angle of instant FFT = $\tan^{-1} \frac{S_{IMAG}}{S_{REAL}}$ |
| j | = | $\sqrt{-1}$ |
| S* | = | Complex conjugate of S = $S_{REAL} - jS_{IMAG}$ |
| (overbar) | = | Ensemble average |
| t | = | Time |
| $\tau$ | = | Artificially introduced time delay |
| $\mathcal{F}\{\}$ | | Direct Fourier Transformation |
| $\mathcal{F}^{-1}\{\}$ | | Inverse Fourier Transform |

(Δ) Similar for Channel B

SECTION 10

DISPLAY (CHANNEL/FORMAT) CONTROLS

## 10. DISPLAY Controls

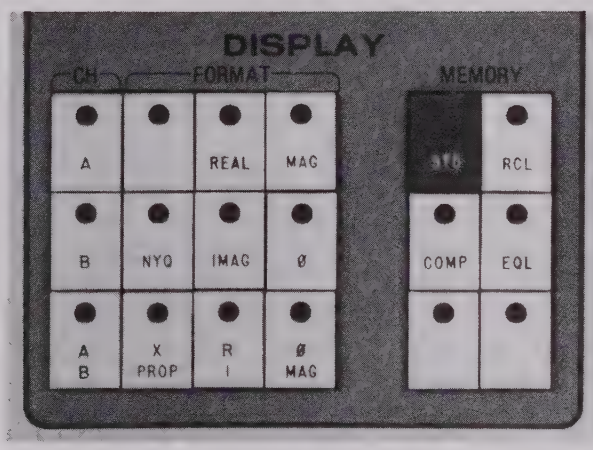



FIGURE 10A

Figure 10A illustrates the display control group. Controls are provided to select a channel (CH) and a format (FORMAT).

The CH pushbuttons select the channel from which the selected function will be displayed. For single channel functions only CHA selection is valid. For dual channel functions, choices of channel A or channel B or channels A & B are provided. The available selections are listed in Table 10-1.

The FORMAT pushbuttons determine how the selected single channel or cross property function will be displayed. The function to be displayed may have one of three format types, namely: complex, magnitude or real. The format types are specified in Table 9-1.

A single complex function contains two pieces of information. In rectangular coordinates these are called the real and imaginary components, while in polar coordinates, they are called the magnitude and phase components.

| | INPT TIME | AVG TIME | IMP RESP | INST SPEC | RMS SPEC | PWR SPEC | COP | CROSS SPEC | TF | TM | COH | AUTO CORR | CROSS CORR | PDF | CDF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A REAL | X | X | | X | | | | | | | | X | | X | X |
| A IMAG | | | | X | | | | | | | | | | | |
| A R/I | | | | X | | | | | | | | | | | |
| A MAG | | | | X | X | X | | | | | | | | | |
| A PHASE | | | | X | | | | | | | | | | | |
| A PH/MAG | | | | X | | | | | | | | | | | |
| A NYQ | | | | X | | | | | | | | | | | |
| B REAL | X | X | | * | | | | | | | | X | | X | X |
| B IMAG | | | | * | | | | | | | | | | | |
| B R/I | | | | * | | | | | | | | | | | |
| B MAG | | | | * | * | * | | | | | | | | | |
| B PHASE | | | | * | | | | | | | | | | | |
| B PH/MAG | | | | * | | | | | | | | | | | |
| B NYQ | | | | * | | | | | | | | | | | |
| AB REAL | X | X | | * | | | | | | | | X | | X | X |
| AB IMAG | | | | * | | | | | | | | | | | |
| AB R/I | | | | | | | | | | | | | | | |
| AB MAG | | | | * | * | * | | | | | | | | | |
| AB PHASE | | | | * | | | | | | | | | | | |
| AB PH/MAG | | | | | | | | | | | | | | | |
| AB NYQ | X | X | | | | | | | | | | | | | |
| XP REAL | | | X | | | | | X | X | | X | | X | | |
| XP IMAG | | | | | | | | X | X | | | | | | |
| XP R/I | | | | | | | | X | X | | | | | | |
| XP MAG | | | | | | | X | X | X | X | | | | | |
| XP PHASE | | | | | | | | X | X | | | | | | |
| XP PH/MAG | | | | | | | | X | X | | | | | | |
| XP NYQ | | | | | | | | X | X | | | | | | |

* Not valid in 2K.
X Valid formats.
XP Cross power functions.

TABLE 10-1. AVAILABLE DISPLAY FORMATS

When a complex function is displayed, its real, imaginary, or both its real and imaginary, RI, may be displayed. Alternatively, the imaginary component may be cross plotted against the real component by selecting a Nyquist display format. Additionally, the same information may be plotted in polar coordinates. Choices of magnitude, phase, or both phase and magnitude may be selected.

For data whose format type is either magnitude or real only those formats are valid, respectively. Refer to Table 9-1 for further clarification.

When a function of either real or magnitude type is selected, the instrument automatically selects the appropriate format. When a complex function is selected, the instrument automatically selects the last manual selection for format.

The 660B has provisions to display one or two traces at a time. This permits the simultaneous display of two real or two magnitude functions or the entire display of a single complex function. Additionally, a single attribute, i.e. magnitude, phase, real, or imaginary, of two complex functions, one from channel A and one from channel B, may be displayed simultaneously. Any two similar traces may be overlapped by depressing OVLP. Attempting to display more than two traces or selecting an improper format may result in an entry/recall field error message. These messages are summarized in Appendix A.

The Nyquist display format button normally is used to cross plot a complex function's real and imaginary components. This format may also be selected to cross plot two time histories, either instantaneous or averaged.

Figures 10B, 10C, and 10D illustrate the CRT annotation reflecting the status of the display controls. In Figure 10B, two instantaneous spectra are displayed. The upper trace is the data from channel A while the lower trace is the data from channel B. Both displays are of spectrum magnitude. In Figure 10C a transfer function (cross property function) is displayed. The upper trace is the phase spectrum while the lower trace is the magnitude (ratio) spectrum. In Figure 10D the real (horizontal) and imaginary (vertical) components of a transfer function are cross plotted in Nyquist format.

In the wake up state, channel is set to A-B while format is set to magnitude.

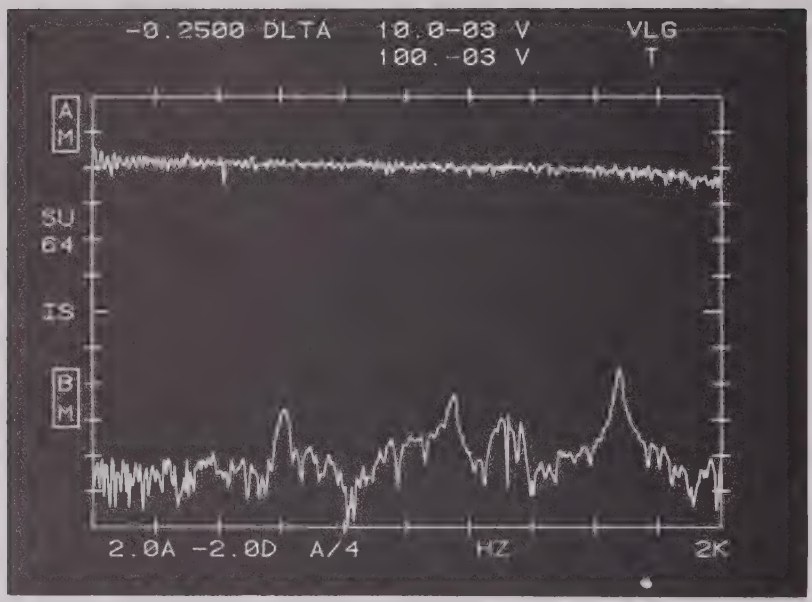



FIGURE 10B

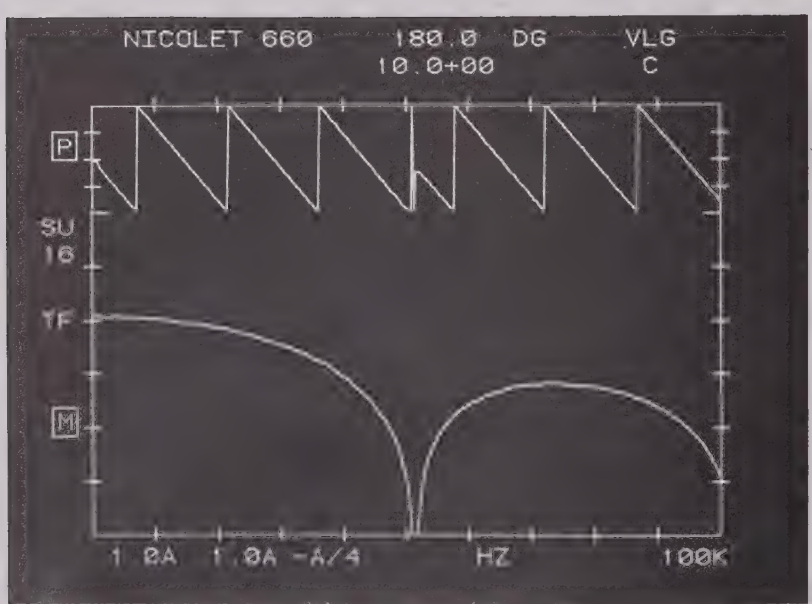



FIGURE 10C

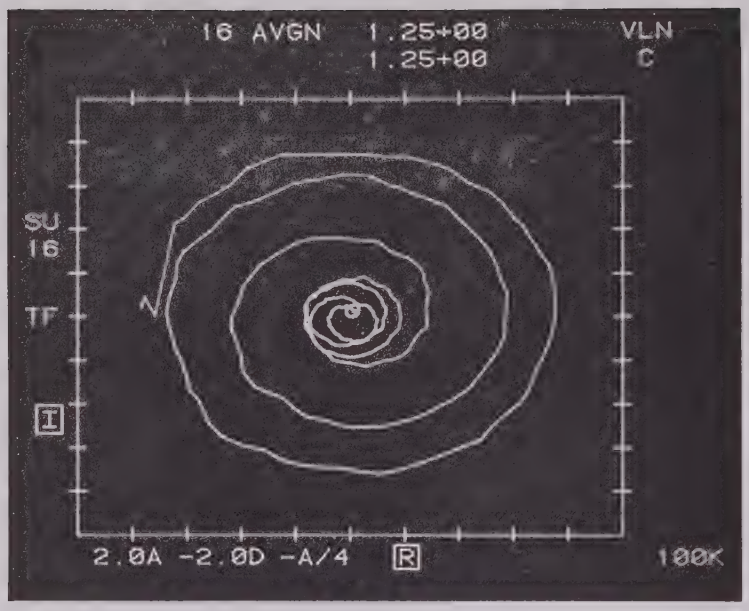



FIGURE 10D

SECTION 11

DISPLAY SCALES CONTROLS

## 11. Display SCALES Controls

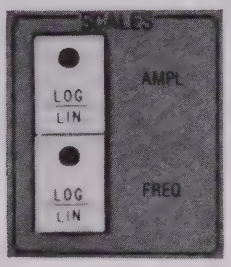



FIGURE 11A

Figure 11A illustrates the SCALES controls. These pushbuttons allow alternate selection of linear or logarithmic horizontal and vertical axes for the CRT display. When logarithmic axes are selected, the LEDs are illuminated. When linear axes are selected, the LEDs are off.

The amplitude scales control only affects functions whose data type is complex or magnitude. Real functions are always displayed with linear amplitude.

The lower frequency scales control affects functions of frequency. Time functions are always presented with a linear horizontal axis.

Both the display form and CRT annotation reflect the status of the SCALES controls. Figure 11B illustrates a power spectrum presented with linear amplitude vs. linear frequency. The vertical axis label, VLN, indicates that the vertical axis of this display is linear. When linear displays are drawn, nine tick marks (10% apart) are always drawn for each data trace. The horizontal axis label Hz indicates that the horizontal axis is linear. Again, tick marks are 10% apart.

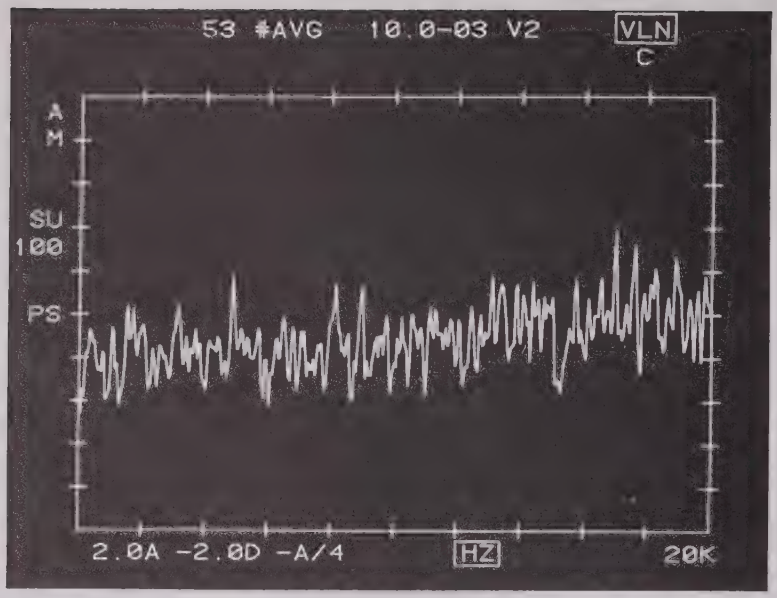



FIGURE 11B

Figure 11C illustrates the same data presented with logarithmic vertical and horizontal axes. The vertical axis label, VLG, indicates that the vertical axis is logarithmic. The tick marks on logarithmic vertical displays are always 10 dB apart. The display range, or number of 10 dB intervals, may be specified through the calculation control group. The horizontal axis label, LGHZ, indicates that the horizontal axis is logarithmic. The tick marks are one decade apart.

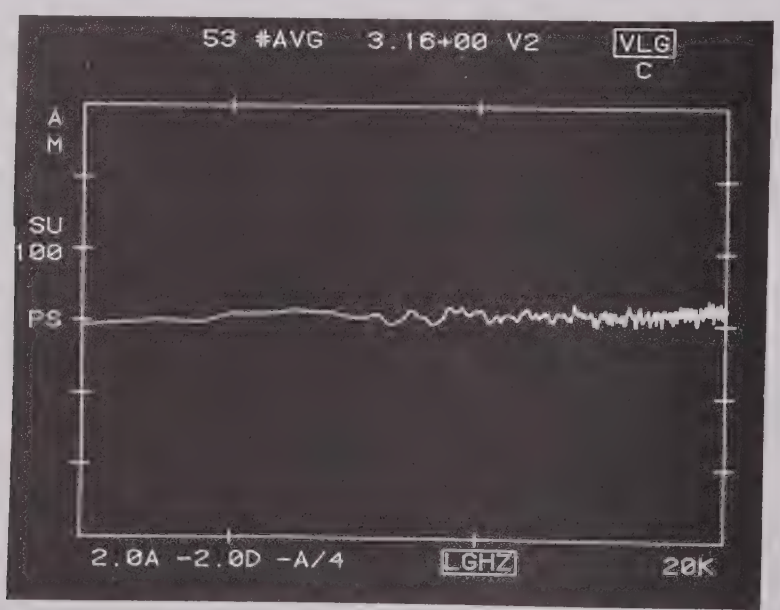



FIGURE 11C

If the FREQ/ORDERS switch is set to ORDERS, the horizontal axis will be labelled OR or LGOR instead of HZ or LGHZ.

In the wake up state the amplitude scale is set to logarithmic while the frequency scale is set to linear. The display range is set to 60 dB.

SECTION 12

DISPLAY GAIN AND UNITS CONTROLS

## 12. GAIN and AMPLITUDE UNITS

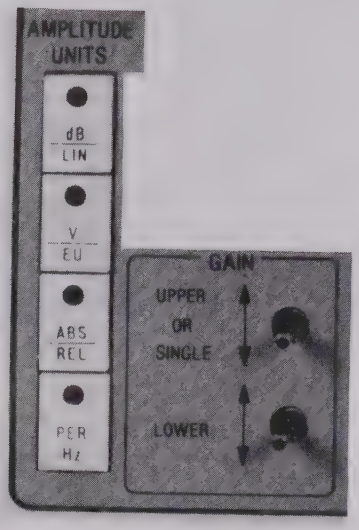



FIGURE 12A

Figure 12A illustrates the controls that select amplitude units and display gain. The pushbuttons grouped under the heading AMPLITUDE UNITS determine not only the cursor readings but the scaling of the display traces. These four pushbuttons perform alternate action selection.

The ABS/REL switch determines whether the vertical units of the display and cursor readout will be in absolute or relative units. Absolute units may be either voltages, as directly measured by the instrument, or engineering units calculated from the voltages readings and engineering unit scale constants. The engineering unit scale constants are entered through the calculation control group. Relative units are ratiometric measurements between two data traces or between two points on a single data trace. Relative measurements are made from a reference value entered through the calculation control group. LIN and DB reference buttons (see Section 16).

The V/EU switch determines whether the absolute units will be volts or engineering units. Changing the status of either V/EU or the ABS/REL pushbuttons will affect the vertical scaling of the data, depending upon the engineering unit scale constants or relative reference entered, and may require changing the gain of the display.

The dB/LIN switch determines whether the display full scales and the amplitude-at-cursor readouts will be in linear units (volts, engineering units, or relative) or in dB (with respect to one linear unit). This selection is independent of the amplitude scales selection.

The alternate action PER Hz switch controls the application of density normalization to displayed spectra. Depressing the PER Hz pushbutton normalizes the amplitude of a displayed spectrum to 1 Hz bandwidth. Density normalization (per Hz) may be applied to five frequency functions as specified in Table 9-1. When the PER Hz pushbutton is depressed the function label is modified by the addition of the suffix D (for density normalization).

The GAIN cursors determine the height of the displayed traces. When a single trace is displayed, the UPPER gain cursor determines the size of the display. When two traces are displayed simultaneously, the UPPER gain cursor determines the height of the upper trace while the LOWER cursor determines the height of the lower trace.

Three exceptions should be noted:

1. When the coherence and cumulative distribution functions are displayed, the gain cursors are inactive. Because these functions are always bounded between zero and one, there is no need for variable display gain. Hence, the bottom of the display is always zero and the top of the display is equal to one when the coherence and cumulative distribution functions are selected.

2. Phase data is normally displayed between ±180° with a 0° display center. While viewing only a single or dual trace phase display, the display center and expansion may be adjusted using the GAIN controls. The UPPER gain control adjusts the phase display center and the LOWER gain control adjusts the expansion (degrees/tic mark). When a phase/mag display is selected the phase display scaling returns to normal. A normal phase display of cross spectrum (CS) is depicted in Figure 12B. The cursor readout indicates the absolute phase of -97.6°. Figure 12C is an example of phase center rotation and expansion. When the cursor is turned off the cursor readout displays (phase display center/degrees per tick mark -95.6/5.6 ).

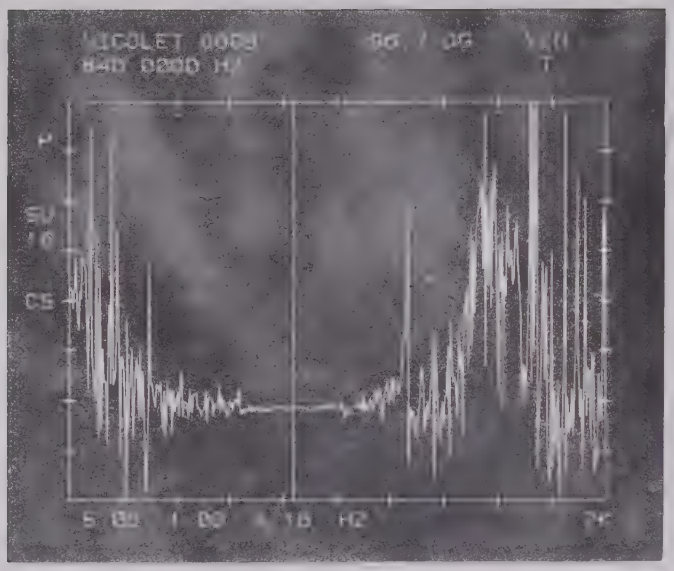



FIGURE 12B

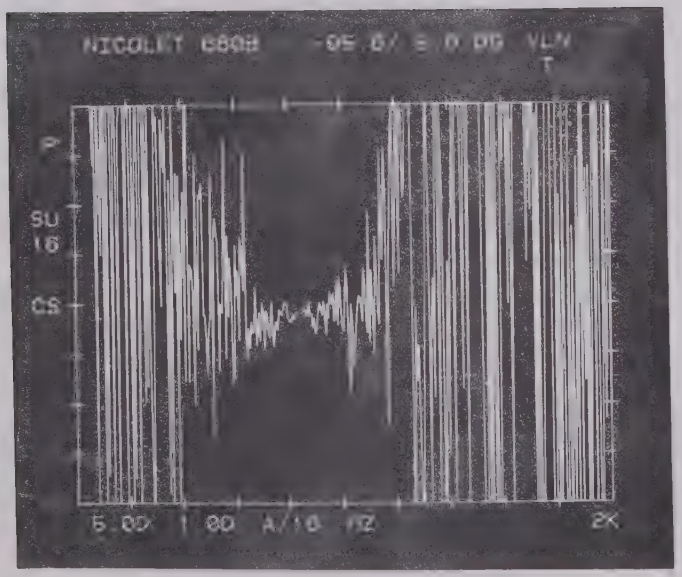



FIGURE 12C

3. When magnitude and phase format is displayed the UPPER cursor determines the gain of the magnitude display. The LOWER gain is inactive.

The GAIN cursors actually determine the full scale value of the CRT display. The 660B automatically scales the displayed data so that the full scale is a nice number. When the AMPL SCALES button is in the linear position, pressing a GAIN cursor downward steps the full scale through the sequence 1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, or 8 times 10 to an integer exponent(_ 39). Raising the cursor steps the full scale through the same sequence in the opposite direction.

Direct keyboard entry of a desired display full scale may be made through the calculation control keyboard. Enter the full scale value (in linear units if the dB/LIN switch is in LIN, in dB if the dB/LIN switch is in dB), SET/STORE, followed by activation of the GAIN switch for the appropriate display. UPPER or SINGLE sets the gain for the upper display if two displays are on screen or the displayed data if only a single display is on screen. LOWER sets the gain for the lower display if two displays are on screen. The gain setting for a single display always corresponds to the gain setting for the upper of two displays.

When the AMPL SCALES selector is in the logarithmic position, moving the GAIN cursor causes the display full scale to change in 10 dB steps. If the AMPLITUDE UNITS dB/LIN button is in the linear position, the full scale will be either 3.16 or 10 multiplied by 10 to an integer power. With this selector in the dB position, the full scale will be an integer power of 10 dB with reference to one physical unit of the displayed measurement.

The CRT display annotation reflects the status of the AMPLITUDE UNITS and GAINs controls as illustrated in Figures 12D, 12E, 12F, 12G. In Figure 12D a power spectrum is displayed. The full scale amplitude of the display in volts$^2$ is displayed. The label V2 indicates that volts$^2$ are being displayed. If an INST or RMS spectrum had been displayed, the label V for volts would have appeared.

In Figure 12E the V/EU selector has been changed from the volts to the engineering unit position. Additionally, the volt per engineering unit scale constants have been recalled to the entry recall field. The physical readout is now in (engineering units)$^2$ as indicated by the E2 label. Readout in linear engineering units is denoted by the symbol E. When using relative measurements rather than absolute, the symbols R and R2 are used. In Figure 12F a power spectrum is displayed with logarithmic amplitude and frequency. Note that the vertical units are volts$^2$ (V2) and that the function label PS indicates a power spectrum is being displayed.

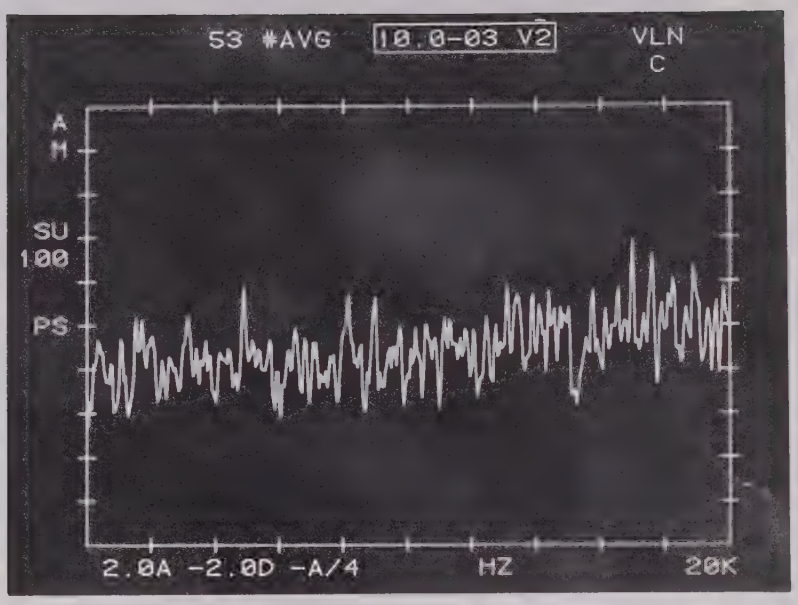



FIGURE 12D

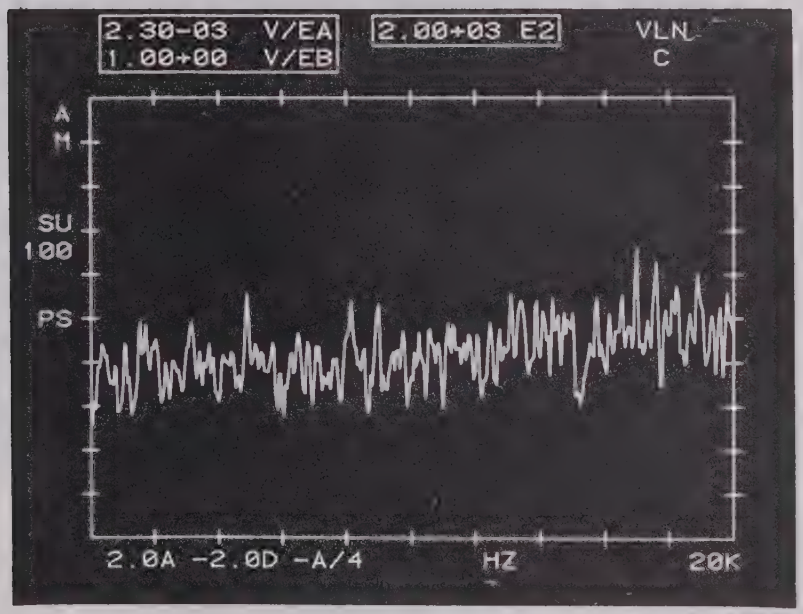



FIGURE 12E

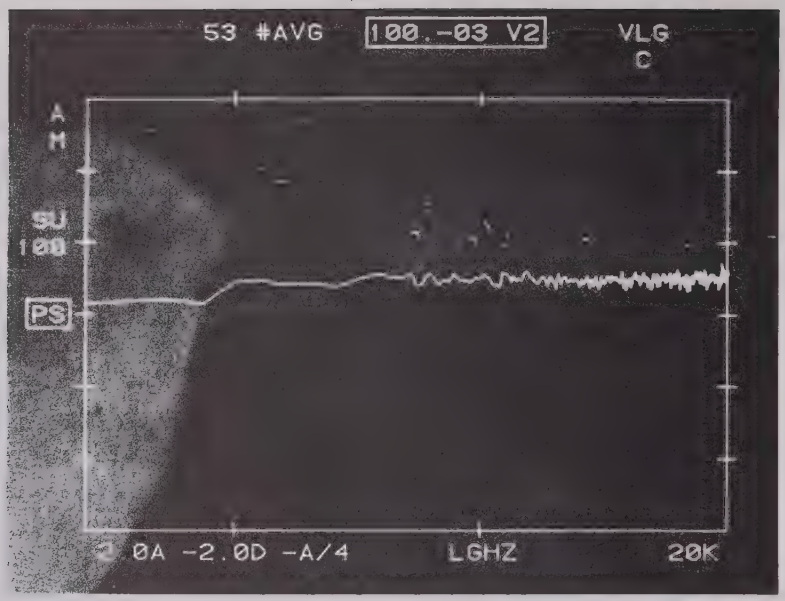



FIGURE 12F

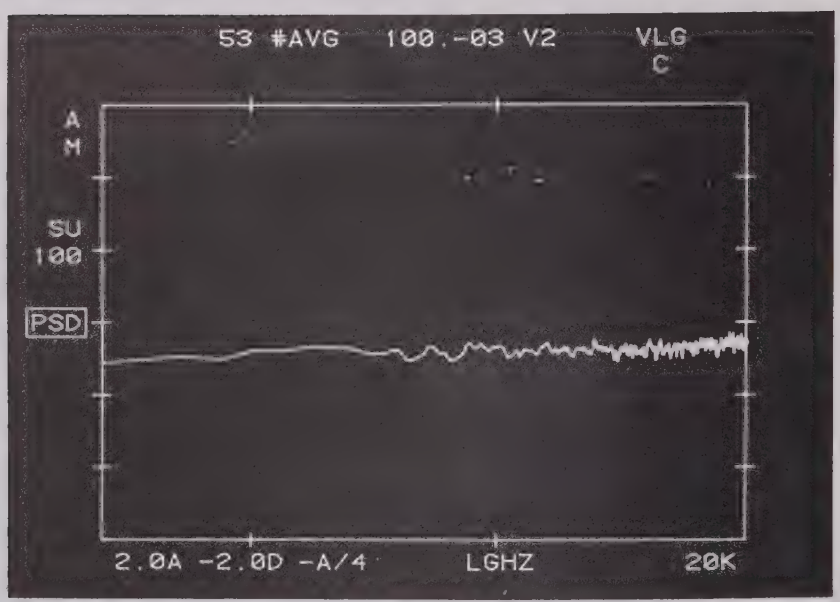



FIGURE 12G

Figure 12G shows the same power spectrum after the PER Hz pushbutton was depressed. Note that the function label has been changed from PS to PSD indicating that density normalization has been applied. The units of the full scale are now volts$^2$/Hz.

Any combination of the pushbuttons under the AMPLITUDE UNITS label is valid. Of course, V/EU scaling is not applied when the cursor readings are ABS (absolute). Note that the units of amplitude measure are 0 to Peak for functions in the time or amplitude domains and RMS for functions in the frequency domain.

In the wake up state the AMPLITUDE UNITS pushbuttons are initialized to linear, volts, absolute and per Hz off. Additionally, the GAIN controls are initialized to match the settings of the maximum amplitude controls.

SECTION 13

CURSOR CONTROLS

## 13. CURSOR POSITION, CURSOR TYPE, and FREQ READS

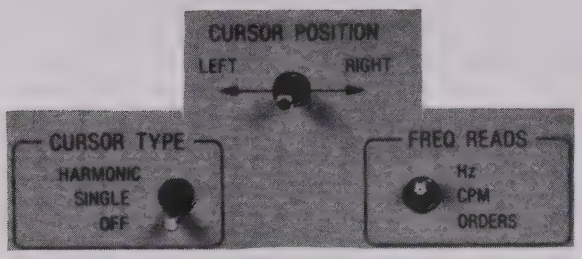



FIGURE 13A

Figure 13A illustrates the cursor control group. The CURSOR TYPE switch permits turning the cursor off, providing a single cursor or a harmonic cursor. Selecting HARMONIC cursor type provides a single line intersecting the data with additional intensified dots at harmonics of the cursor position.

When the cursor is turned on, the CURSOR POSITION switch permits positioning the cursor left or right. Touching this control once advances the cursor one location. Holding this control to the left or right causes the cursor to slew. Alternatively, the cursor position may be explicitly selected through the CALCULATION CONTROL group.

The FREQ READS selector affects the readout of horizontal units. Normally, horizontal readout is in Hz for frequency functions, is in seconds for time functions, and is in voltage or engineering units for amplitude functions. The FREQ reads switch only affects functions of frequency or time. In the Hz position, units of Hz and seconds are used. In the CPM position, units of cycles per minute are displayed in frequency, and fractions of time windows (specified by the frequency range) are displayed in time. In the ORDERS position, orders (normalized frequency) are used for frequency

and units of cycles (inverse orders) are used for time. The order reference is established through the calculation control group. See Table 13-1.

When the FREQ/ORDERS switch is in the ORDERS position, the sampling frequency for input time conversion is supplied by the user. Since the 660B Analyzer does not know the relationship of this sampling frequency to the input time signal, it is not possible to properly annotate time or frequency in terms of Hz and CPM but rather must annotate data in terms of samples or orders (that is frequency ratio). The readings obtained when the FREQ/ORDERS switch is in the ORDERS position are shown in Table 13-2.

Figure 13B illustrates a CRT display with the cursor turned on. The cursor takes the form of a vertical line intersecting the data trace or traces. The horizontal position of the cursor is read out directly below the entry recall field. In this example, the frequency readout is presented in Hz.

When the cursor is turned on, the amplitude at its location replaces the full scale annotation. Comparing Figure 13B and 12D show this replacement. The readout units for full scale and cursor amplitude are consistent.

The "wake-up" state uses the positions of the CURSOR TYPE, FREQ READS, OR CURSOR POSITION controls.

The cursor may be explicitly set by either of two methods:

Display Cell Number:

Enter the desired cursor cell number (1 to 400 for 400 point frequency displays, 1 to 800 for 800 point frequency displays, 0 to 1023 for 1024 data time display, 0 to 2047 for 2048 point time displays, 1 to 127 for amplitude displays), followed by the decimal point, SET/STORE, and the CUR LOC key. This sequence causes the immediate movement of the cursor from its current position to the specified cell.

Annotated Units:

Enter the desired cursor horizontal location in the currently annotated units (i.e. Hz, CPM, etc.), followed by the SET/STORE and a left or right movement of the CURSOR POSITION switch. This sequence causes the immediate movement of the cursor from its current position to the position nearest the specified location.

The number of data points displayed on the CRT varies with the operating mode. In the 2K FFT mode 2048 time points can be displayed where as only 128 points are displayed in the probability mode. Normally, if the cursor were to be

TABLE 13-1

HORIZONTAL READOUT AT CURSOR

FREQ/ORDERS SWITCH SET TO FREQ

| | DOMAIN OF DISPLAYED FUNCTION | | |
|---|---|---|---|
| FREQUENCY READS SETTING | TIME | FREQUENCY | AMPLITUDE (PROBABILITY) |
| Hz | SECONDS | Hz | VOLT OR EU |
| CPM | FS | CPM | VOLT OR EU |
| ORDERS | CYC | ORD | VOLT OR EU |

Hz = Hertz (Cycles/Second)
CPM = Cycle/Minute
ORD = Order (Frequency Ratio)
FS = Fraction of Full Scale
(Frequency Range or Time Window)
CYC = Cycles ($Order^{-1}$)
\# = Point or Cell Number

TABLE 13-2

HORIZONTAL READOUT AT CURSOR

FREQ/ORDERS SWITCH SET TO ORDERS

| | DOMAIN OF DISPLAYED FUNCTION | | |
|---|---|---|---|
| FREQUENCY READS SETTING | TIME | FREQUENCY | AMPLITUDE (PROBABILITY) |
| Hz | # | # | VOLT OR EU |
| CPM | FS | FS | VOLT OR EU |
| ORDERS | CYC | ORD | VOLT OR EU |

Hz = Hertz (Cycles/Second)
CPM = Cycle/Minute
ORD = Order (Frequency Ratio)
FS = Fraction of Full Scale
(Frequency Range or Time Window)
CYC = Cycles ($Order^{-1}$)
\# = Point or Cell Number

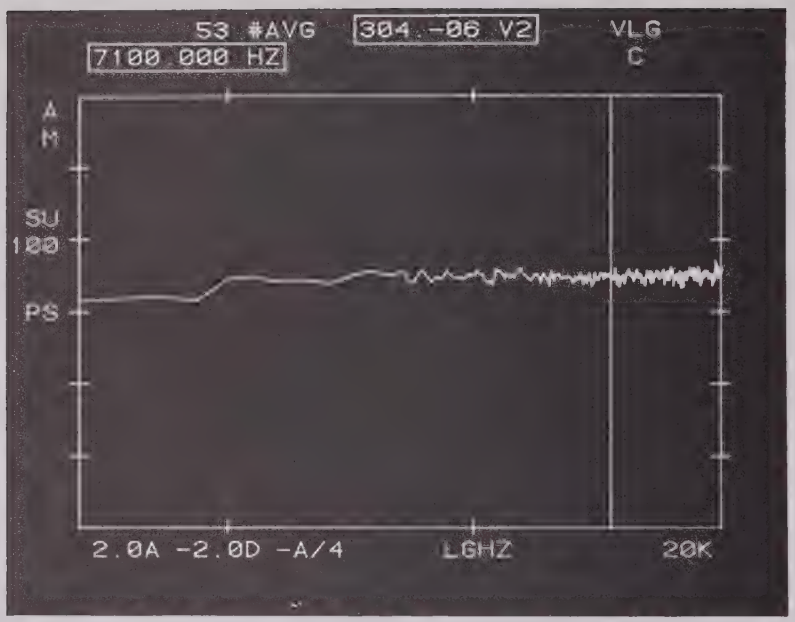



FIGURE 13B

moved at a constant number of data points per second, it would take much longer to move from one end of the display to the other in the 2K mode than it would in the probability mode. In order to have the slew rate fairly constant independent of display, the cursor is stepped more than one cell location depending on the display. These larger step sizes occur only during sweeping. Single stepping of the cursor always is one data point per step.

TABLE 13-3

CURSOR LARGER STEP SIZE BY DISPLAY TYPE

| Display | Cells on Display/128 | Larger Step Size Cell |
|---|---|---|
| Time Display | 1024 | 8 |
| (2K FFT Mode) | 2048 | 16 |
| Frequency Display | 400 | 3 |
| (2K FFT Mode) | 800 | 6 |
| Probability Display | 128 | 1 |

The larger step size provides the user with a constant cursor range speed despite the amount of data on display. This larger step is 1/128 of the data cells on display and the above table gives the exact amount in each case.

SECTION 14

OUTPUT TYPE CONTROLS

## 14. OUTPUT TYPE

FIGURE 14

Figure 14 illustrates the OUTPUT TYPE controls. These controls specify the target for data output by the 660B. Output targets include analog and digital devices.

Depressing the CRT ONLY pushbutton cancels all other forms of output from the instrument. CRT ONLY is the default status of the instrument. Unless another pushbutton in the output type group is depressed, output of the instrument is to the internal CRT only.

Depressing the AUX pushbutton causes digital or analog output to be channeled to an auxiliary device. The nature of the transmission is specified through the DEF AUX key in the calculation control group. After the AUX key is depressed and its LED is illuminated, depressing the PLOT key causes digital output to the optional Model 134A Digital Plotter, or to the optional Model 136A Digital Plotting Adapter. With alternative entries to the DEF AUX, depressing this pushbutton can cause analog output equivalent to the current cursor to appear on the analog plotter terminals (rear panel) or data transmission through the RS232 or IEEE-488 interfaces. The 80 DEF AUX series provides automatic pagination for use with the Model 136A Digital Plotting Adapter. The second digit of the series indicates the number of pages (8 1/2 x 11) the paper is to be advanced after each plot (e.g. 81 causes the 136A to position to the next page, ready for the next plot). Details of the define auxiliary entries are contained in

Section 19, Digital Interfaces. The LED on the AUX pushbutton remains lit for the duration of auxiliary data transmission. The transmission may be terminated manually by pressing the CRT ONLY pushbutton.

The PLOT CAL pushbutton is used in conjunction with an optional analog X-Y plotter and the optional 136A Digital Plotting Adapter. The first time this pushbutton is depressed, an output voltage is applied to the horizontal and vertical plotter outputs corresponding to the lower lefthand corner of the display. The second time this pushbutton is depressed, the voltage at those terminals is changed to correspond with the upper righthand corner of the display. The third time this pushbutton is depressed, the PLOT CAL mode is exited.

When a two trace display is drawn, depressing the PLOT CAL pushbutton steps the voltages on the horizontal and vertical plotter outputs through a sequence corresponding to:

1. Lower lefthand corner of upper trace
2. Upper righthand corner of upper trace
3. Lower lefthand corner of lower trace
4. Upper righthand corner of lower trace
5. Exit PLOT CAL mode

The PLOT CAL mode is also exited if any of the remaining OUTPUT TYPE pushbuttons is depressed. If the AUX key has been depressed and its LED is illuminated, depressing the PLOT CAL pushbutton causes the output of the graticule corners over the RS232 or IEEE-488 interface, depending on the setting of the 0 series DEFine AUX (see Figure 19-3). This feature allows the user to place the plotted graticules at specific locations on the plotter page. Refer to the 136A Plotter Manual for a further description of this sequence.

Depressing the PLOT pushbutton causes analog outputs necessary to draw the data of the screen image on an analog plotter to appear on the rear panel vertical and horizontal plotter outputs. Analog plotter output consists of data traces only, no graticule or annotation information is output.

When a plot is initiated by depressing the PLOT pushbutton, the CRT image remains unchanged. A single intensified dot is seen to scan across the CRT image, indicating the position of the analog plotter's pen. At the conclusion of the plot, the voltage outputs on the rear vertical and horizontal axis terminals correspond to the last data point in the display. The PLOT LED is extinguished.

Following a plot, depressing the CRT ONLY pushbutton clamps the plotter output levels to zero volts.

In addition to horizontal and vertical axis plotter outputs, the 660B provides a pen lift output. This output is a switch closure used for lowering the pen on an analog plotter. When the PLOT button is depressed, the switch closure is made. Followin a plot, when the CRT ONLY pushbutton is depressed the switch closure is opened.

In the wake up state the 660B is placed in the CRT ONLY mode. The define auxiliary is specified to support the 134A Digital Plotter and the 136A Digital Plotting Adapter via RS232.

SECTION 15

DISPLAY MEMORY

## 15. DISPLAY MEMORY Controls

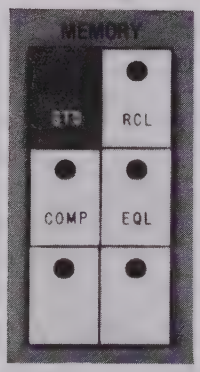



FIGURE 15A

The DISPLAY MEMORY controls are shown in Figure 15A. These controls are annotated with the letter D. The STO C and VIEW C pushbuttons control features of the Spectrum Calculation Option -8. Information for these features is contained in the Options Section of this manual.

The Display Memory controls permit storage, recall, comparison, and equalization of data. A single screen image of one or two traces may be stored in its entirety. A stored screen image may be recalled for display at a subsequent point in time. When data is recalled, the display reflects the control status of the instrument at the time the data was stored, even though control changes may have been made between the time the data was stored and recalled.

Facility is provided to compare the stored measurement with its currently measured equivalent. When two traces have been stored from a single screen image, the comparison is limited to two display traces, one from the currently measured function and one from the stored function. Either of the two stored traces may be compared.

If the stored information is a transfer function, it may be used to equalize a currently measured transfer function, transmissibility function, or impulse response. Equalization is a means of correcting for phase and amplitude shifts introduced by test measurement components external to the 660B. This function is particularly useful when analyzing data which has been tape recorded.

When the STO D pushbutton is depressed, the currently displayed screen image, one or two traces, is stored in the display storage memory. The entry/recall field indicates that storage has occurred by displaying the message DATA STORED as shown in Figure 15B.

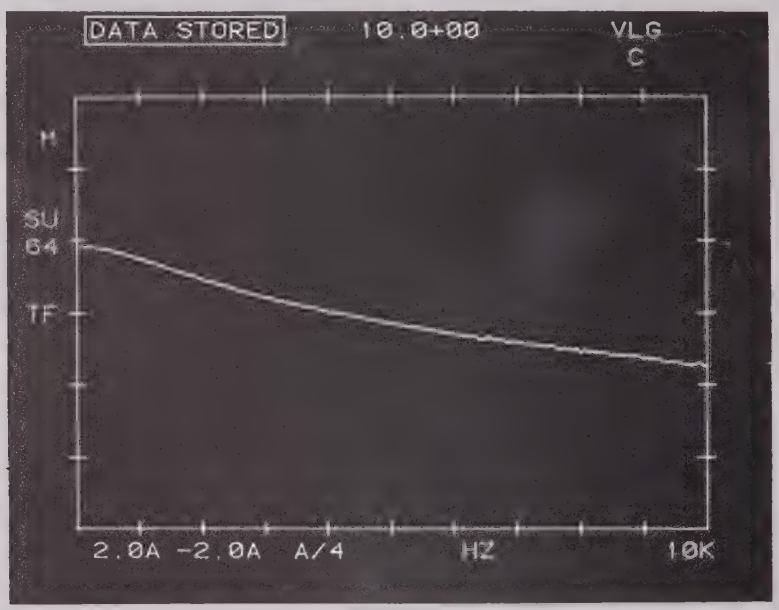



FIGURE 15B

Depressing the RCL D button causes the stored display to replace the currently measured display. Depressing this pushbutton a second time reverts the display to the currently measured function that was on display before the recall button was first depressed. When the recall button is depressed, the screen annotation reflects the status of the instrument at the time of storage. All parameters that may be recalled through the entry/recall field reflect the status of the instrument at the time the data was stored. When the RCL button is depressed the second time, the currently measured function returns to the CRT with all parameters, gains, etc. restored to the condition that they held prior to the recall of the stored information.

Modifications to the stored panel settings are permitted in the recall mode. If the STO D pushbutton is again depressed, the new front panel settings are stored with the old data.

Depressing the compare COMP D pushbutton causes the display of the stored function and its currently measured equivalent as shown in Figure 15C. In Figure 15C the magnitude of two transfer functions is compared. The upper trace is always the current measured function, while the lower trace is the stored function. These two traces may be overlapped by pressing OVLP (see Section 10). Note that only two traces may be displayed at one time. Hence, with a transfer function or any complex function or pair of single channel functions stored, the comparison must be made one trace at a time.

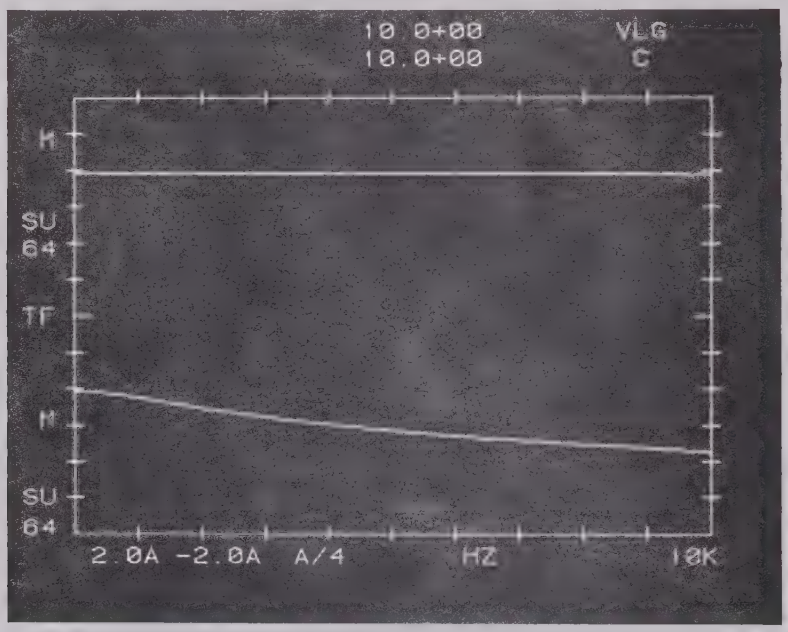



FIGURE 15C

Comparisons can only be made between like functions acquired under similar conditions. For example, a probability density function cannot be compared with a transfer function. For this reason, if the COMP pushbutton is depressed and the currently displayed function does not match the stored function, the entry/recall field will display the error message RECALL, MATCH. This instruction advises the user to recall the stored information and then display its currently measured equivalent before depressing the COMP D pushbutton.

Attempting comparisons with channel AB or format RI or format Ø MAG or format Nyquist will produce the error message ONLY 2 TRACES. This message instructs the user to select the channel or format of the currently measured function to produce only a single trace before depressing the COMP D button.

If a transfer fucntion has been stored, the equalize (EQL D ) pushbutton may be used. If the stored data is not a transfer function, the error message TF NOT STORED will be

presented in the recall field. Equalization can be applied to the transfer function, transmissibility function, and impulse response. No other functions can be equalized. /

Depressing the equalize pushbutton performs the complex division (equalization) of the currently measured transfer (or transmissibility) function by the previously stored transfer function. Co.plex division is equivalent to dividing the magnitude of the currently measured transfer (or transmissibility) function by the magnitude of the stored transfer function. Additionally, the phase spectrum of the stored transfer function is subtracted from the phase spectrum of the currently measured transfer function. Figure 15D illustrates the equalized transfer function display of Figure 15C. Note that the function label has been modified by appending the prefix E for equalized to the function label TF. As shown in Table 9-1, modified labels of ETF, ETM, and EIR are possible.

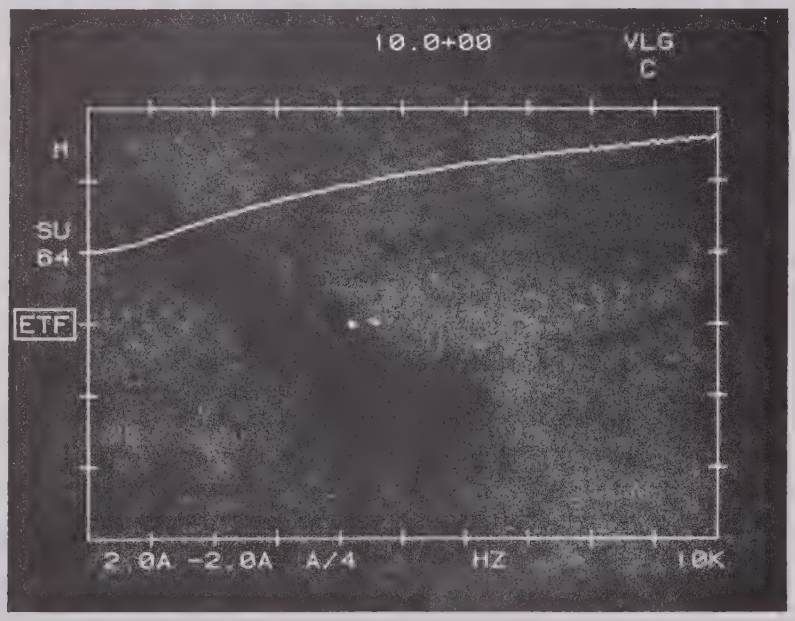



FIGURE 15D

When the currently selected measurement function is the impulse response, the equalization operation is first applied to the currently measured transfer function. Next, this equalized transfer function is inverse Fourier transformed to provide the equalized impulse response (EIR).

Attempting to depress the RCL D, COMP D , or EQL D pushbuttons without previously storing a screen image will result in the entry/recall error message NO STORED DATA. This message indicates that the user must first store a screen image before attempting to use one of these functions.

In the wake up state no data is stored.

## 16. CALCULATION CONTROL

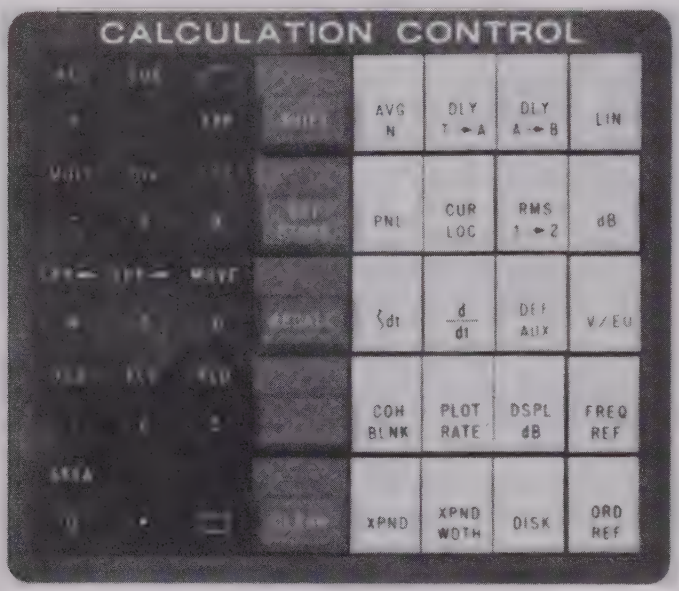



FIGURE 16A

Figure 16A illustrates the calculation control group. This control section is used to enter numeric information to the processor, to recall operating statuses of the instrument, and to modify the behavioral performance of the 660B. Transactions through the calculation control are displayed in the entry/recall field as they occur. Unless deliberately cleared, or otherwise used, the entry/recall field always displays the last transaction conducted with the calculation controls.

Four types of transactions may be conducted. These include:

1. Data may be entered using the SET/STORE key.
2. Information may be interrogated using the RECALL key.
3. An operation or characteristic initiated through a SET STORE command may be returned to the wake up state condition by using the CLEAR key.
4. Special operations involving the ENTRY/RECALL field are initiated through the SHIFT 1 and SHIFT 2 keys.

Data entries are always with a left-to-right sequence. A number is typed, followed by touching the SET STORE key, and normally followed by touching one of the twenty white buttons on the righthand side of the calculation control group. Data entries may be made in integer or floating point format.

The EXP key is used to enter exponents. This key permits direct floating point entry. For example, the number 35,000 may be entered using the keystroke sequence 3, 5, EXPonent, 3 (35 times $10^3$). All entered numbers are assumed to be positive unless the minus (-) key is depressed before depressing either the EXP or SET STORE keys. Exponents, when used, are assumed positive unless the minus key is depressed after touching the EXP key and before depressing the SET STORE key. Leading zeros are ignored and the use of the decimal point is optional. There is no one correct way to enter a number. Any of several possible entries can be valid. For example, to enter the number .018 all three of the following keystroke sequences are valid:

1. Minus, decimal point, 0, 1, 8
2. Minus, 1, 8, exponent, minus, 3
3. Minus, 1, decimal point, 8, exponent, minus, 2

Most data entries involve entering a number, followed by the SET STORE, and followed by one of the twenty white pushbuttons. The exceptional operations are to explicitly set the display gains and the cursor location from the keyboard. Refer to Section 13 for direct cursor setting and to Section 12 for direct gain setting.

The use of the decimal point is optional in normal data entries.

Depressing the CLEAR key clears the entry/recall field. This key may be used to eliminate an erroneous numeric entry. Depressing the CLEAR key, followed by one of the twenty white calculation control keys will clear that function to its wake up state condition.

Depressing the RECALL key, followed by one of the twenty white keys will cause the previously entered value to be displayed in the entry/recall field. Thus, any parameter of significance can be brought to display prior to photographing or hardcopying the CRT image. Further, any numeric entry typed through the calculation control group without the following SET STORE and function button sequence may be left on display for hardcopy. This permits entering identification numbers on screen images.

The twenty white calculation control keys each have defined functions. These are listed, with a description of their use and their wake up state conditions, in Table 16-1. The DEF AUX key is discussed in greater detail in Section 19. Appendix A reviews the entry/recall field messages that may be generated by improper use of the CALCULATION CONTROL. The following figures illustrate typical operations conducted through the calculation control group.

In Figure 16B the screen image of a captured transient time history is shown. The left most data point in this display is the first one which satisfied the transient conditions specified by the capture controls. In this instance, it is desired to view some information prior to trigger conditions.

In Figure 16C a similar transient has been captured after typing the sequence, minus, .125, SET, DLY T->A. This sequence established an anticipation (negative delay) between the trigger point and the first data point held. Notice that the capture point has been moved to 12.5% (.125) of the time window. Delays ranging from -1 to +63 time windows with resolution of 1/1024 windows may be entered through this key. Additionally, delays between channel A and B of 0 to 64 time windows may be entered using the DLY A->B key.

Figure 16D illustrates an RMS spectrum. Figure 16E shows the same data after the keystroke sequence, 2, SET, $\int dt$ has been made. This keystroke entry must be made while viewing a single channel frequency function. The result of this keystroke entry provides artificial integration for the viewed channel. One or two integrations may be specified. Artificial integration is performed by $j\omega$ division in the frequency domain. Thus, if the data in Figure 16D had represented an acceleration spectrum then that in Figure 16E would have represented a displacement spectrum.

It is sometimes desirable to change the display range. Figure 16F presents the same data as that of Figure 16E, but the keystroke sequence, 80, SET, DSPL dB, has been entered. This entry changed the range of display from the wake up state of 60 dB to 80 dB. Selections from 20 to 160 dB, in 20 dB steps, may be made.

The coherence function is often used to qualify the believability of a transfer function (or other cross property function) as a function of frequency. The qualification can be activated in the Model 660B by entering the keystroke sequence, .9, SET, COH BLNK. This sequence specifies a coherence blanking level of 90%. The transfer function displayed in Figure 16G is blanked at all frequencies where the associated coherence function is less than .9.

Other important calculation control operations include establishing volt/engineering unit scale constants. These may be entered by using the V/EU keys or the LIN and dB keys in conjunction with the cursor. The FREQ REF and ORD REF keys are also used conjunction with the cursor to modify horizontal readouts. The CUR LOC key may be used to store up to ten cursor locations for immediate recall through the keyboard. The entire operating status of the front panel may

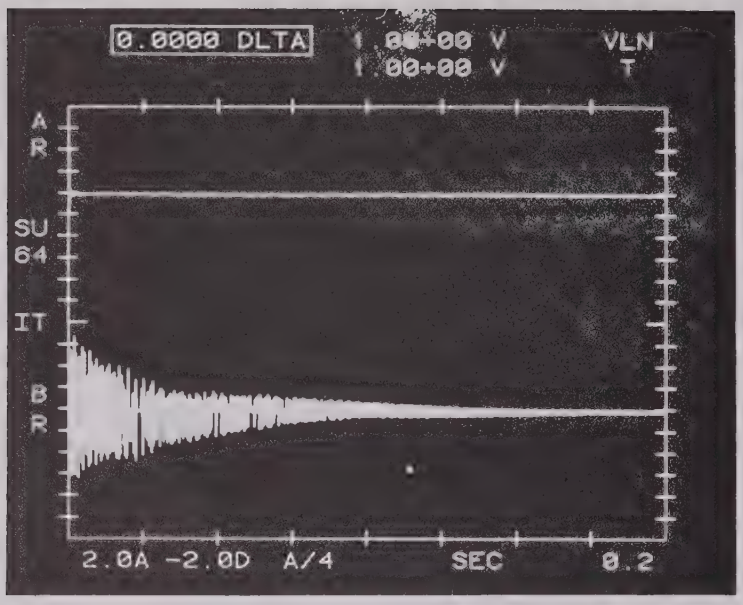



FIGURE 16B

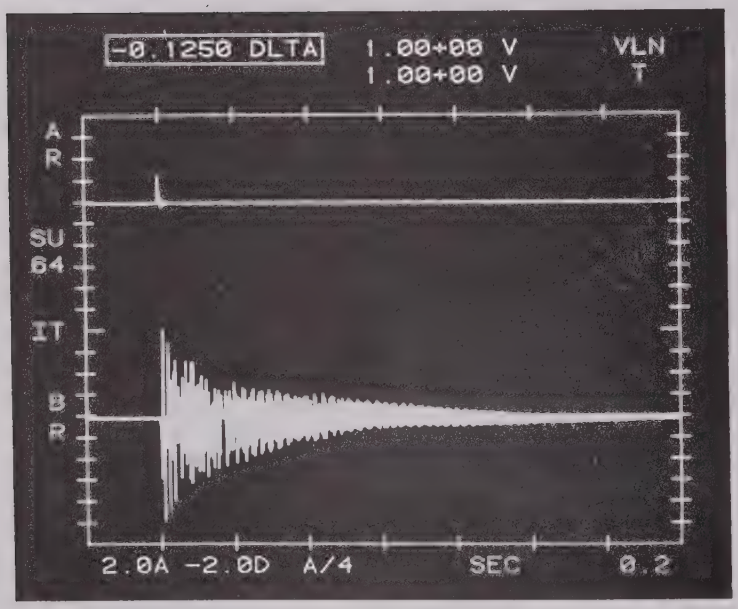



FIGURE 16C

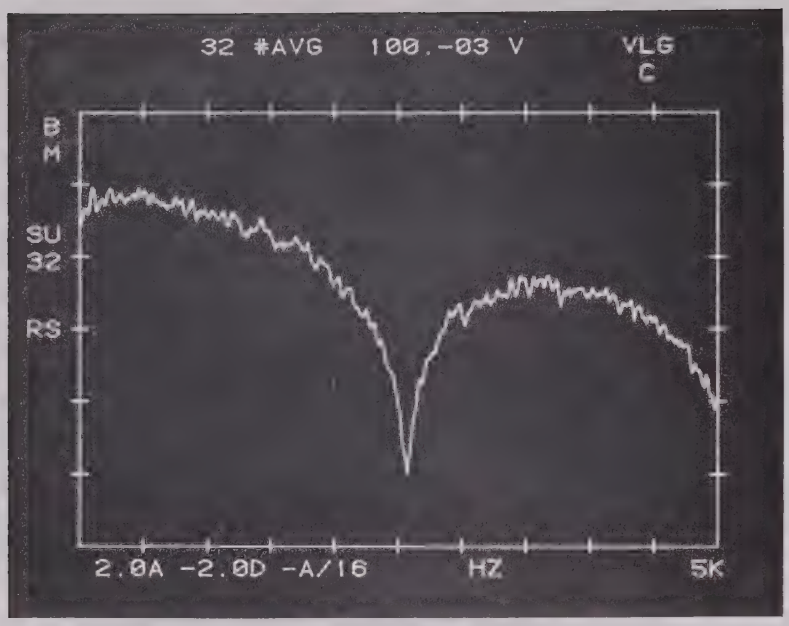



FIGURE 16D

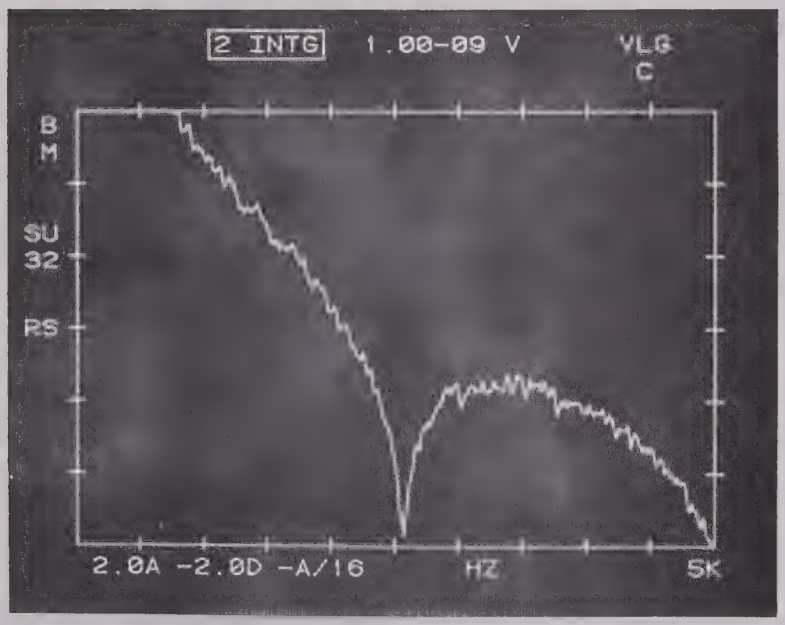



FIGURE 16E

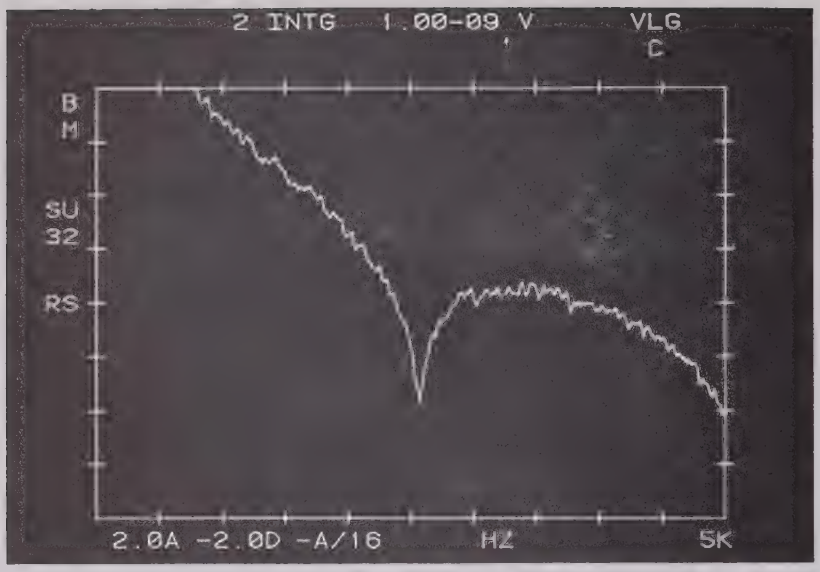



FIGURE 16F

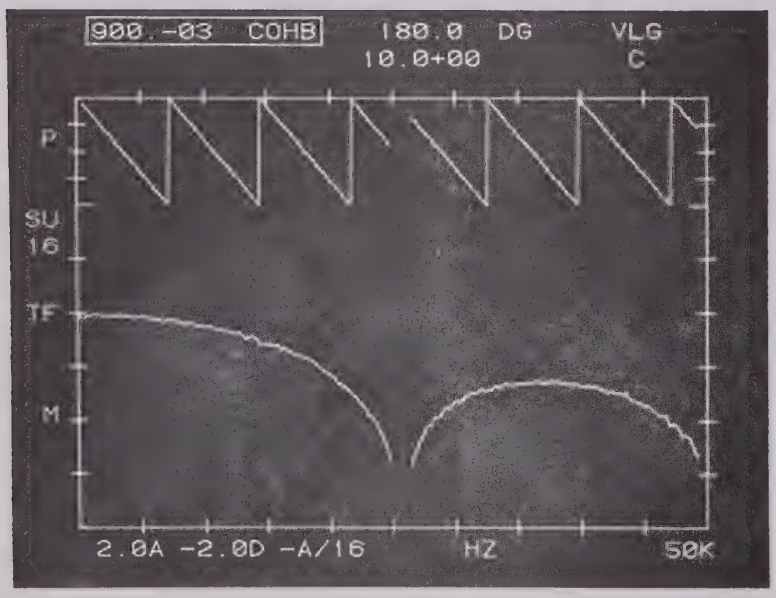



FIGURE 16G

be stored for future use by using the PNL key. This key permits storing up to ten entire front panel statuses so that they may be rapidly recalled with a single key sequence. Stored panel settings are retained even if the instrument is turned off.

Obviously, the calculation control group expands the versatility and flexibility of the 660B. This group of controls is the key to tailoring the instrument's response to the user's needs. Table 16-1 summarizes the operations provided by this control group.

Table 16-2 summarizes the entry field operations available. These functions are activated by depressing one of the blue SHIFT keys followed by a black numeric key to execute the operation indicated on the upper portion of each black key. These operations are separated into three types, namely, math, text, and informational.

The math feature allows numbers to be brought to the entry/recall field, operated upon (chaining calculations allowed), and then used to "SET" all available functions. For example, to multiply 3.1 by 4.2; add 6.1; take the square root; and finally set the result as upper display gain (full screen value), the sequence is:

| | | | |
|---|---|---|---|
| 1. | Enter: | 3.1 | Follow normal procedures |
| 2. | | SET | SET also places value in math accumulator |
| 3. | Enter: | 4.2 | |
| 4. | | MUL | Sequence SHIFT 1; '7' |

Intermediate result of 13.02 should appear in the Entry/Recall field.

| | | | |
|---|---|---|---|
| 5. | Enter: | 6.1 | NO CLEAR, simply enter new number |
| 6. | | ADD | Sequence SHIFT 1; '+' |

Intermediate result of 19.12 should appear.

| | | |
|---|---|---|
| 7. | $\sqrt{\phantom{x}}$ | Sequence SHIFT 1; '+' |

Result of 4.373 should appear.

| | | |
|---|---|---|
| 8. | SET | |
| 9. | GAIN (Upper) | Momentary deflection of the upper gain joystick sets the value |

If the cursor is on, turning it off will display the FULL SCALE of each trace. This should confirm that the results of the calculation were used to SET the full scale of the upper trace.

TABLE 16-1

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 1a. Set N, the number of spectra in the average | *Number (1-9999) SET AVG N | Causes averaging to stop after N spectra in the SUM or DIFFerence averging modes, or determines the averaging time constant (speed of response) in Exponential. (In Ex, the next lower power of "2" is automatically employed.) Averaging in PEAK and SWEEP modes continues until STOP is pushed, regardless of N. In Ex (only), can change N without stopping averagng. (Initialized to "16".) |
| 1b. Reads N | RECALL AVG N | Number of spectra averaged to the moment appears in the display. |
| 2a. Set time from a trigger to the start of CHA time window | *Number (-1.000 to 63.000 for "1K") *Sign (-means anticipation) SET DLY T->A | Delays (+) or anticipates (-) the capture of a transient from either an enternal trigger or a trigger level on the transient itself (see CAPTURE CONTROL) in terms of time windows. Resolution of the setting is 1/1024 of time window or approximately .001 ("in 1K CHA-B mode"). The time window is determined by the setting of the FREQUENCY RANGE. (For DUAL 1K mode, maximum is 31 time windows and resolution is 1/2048 time windows or approximately .0005.) |
| 2b. Read time from trigger | RECALL DLY T->A | (Initialized to "0000" time windows, i.e., no delay with the left edge of the time display the instant triggering.) |

(+) All numbers are assumed positive if no sign is entered. * Indicates number is stored with panel setting with PNL mode. "Initialized" number is automatically set when the unit is turned on or when the SYStem ReSeT is pushed. () After number indicates the range of possible numbers.

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 3a. Set time delay between CHA and CHB | *Number (0.000 to 64.000) DLY A->B | When collecting and processing two channels of data, sets time delay of CHB data with respect to CHA data in terms of time windows in order to compensate for delays inherent in the experiment, e.g. transport delays. Resolution of setting is 1/1024 x time window or one sample. Time window is determined by setting of FREQUENCY RANGE. |
| 3b. Read time delay from CHA to CHB | RECALL DLY A->B | (Initialized to "0", or no delay.) |
| 4a. Set calibration at cursor in engineering units | Number EXP Sign Number (0 to 33) SET LIN | When displaying a single ch. INSTant SPECtrum or RMS SPECtrum, a known amplitude reading is assigned to a spectrum element identified with the cursor (cursor in LINear EU). Exponent seeks a multiple of "3" and the decimal point automatically readjusts for no more than 3 decimal places. Two different EU calibrations can be entered (ABS/REL). The RELative number can be entered to allow measurement of amplitude differences from one spectrum peak to another. |
| RECALL DEFAULTS TO ITEM 6. | | |
| 4b. Measure in engineering units | (Reads at all times in the annotation in LINE-EU settings of AMPLITUDE UNITS buttons) | See Item 6. |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 5a. Set calibration at cursor when reading amplitudes of frequency functions in db | *Sign (+, -)<br>*Number (0.0 to 299.9<br>SET<br>dB | When displaying single channel INSTant SPECtra or RMS SPECtra, a known dB reading is assigned to a spectrum element identified with the cursor. Two different dB calibrations can be entered, one in ABSolute, one in RELative. |
| RECALL DEFAULTS TO ITEM 6 | | |
| 5b. Read calibration in dB of frequency function | (Reads at all times in the annotation in dB-EU settings of AMPLITUDE UNITS buttons) | See Item 6. |
| 6a. Set sensitivity of test system (including analyzer) in volts per engineering unit | *Number<br>*EXP<br>*Sign (+, -)<br>*Number (0 to 30)<br>SET<br>V/EU | When displaying single channel INSTant SPECtra or RMS SPECtra, a known calibration equivalence is established between volts and engineering units. The exponent automatically seeks a multiple of "3" and the decimal point automatically readjusts for no more than 3 decimal places. (ABS/REL switch in AMPLITUDE UNITS must be in ABS.) |
| 6b. Read sensitivity in V/EU | RECALL<br>V/EU | Reads sensitivity of both input channels in any dual channel display or dual channel function. (Initialized to 1.0 V/EU.) |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 7a. Retain settings of panel controls and keyboard | Number (1 to 9)<br>SET<br>PNL | Stores all pushbutton settings and all keyboard settings indicated by "*". Also stores all other pushbutton settings (scales, modes, display, etc.). Does not store cursor location or AVERAGE START/STOP. Nine I.D. numbers are available. Total of 10 panel patterns can be stored (including "0", as defined below). |
| 7b. Recall settings of panel controls keyboard | Number (0 to 9)<br>RECALL<br>PNL | Re-establishes panel control settings indicated by "*" for each of ten numbered patterns. Panel settings at moment of recall are stored automatically as "0". |
| 8a. Retain current cursor location | Number (1 to 9)<br>SET<br>CUR LOC | Stores location of cursor in frequency displays when cursor is on. |
| 8b. Recall past cursor location | Number (0 to 9)<br>RECALL<br>CUR LOC | When stored cursor locations are recalled, the present one is automatically stored as "0" and can be recalled as "0". Initialized at mid-screen. |
| 9. Calculate RMS power between two frequencies | Number "n"<br>(0 to 9)<br>Number "m"<br>(0 to 9)<br>RECALL<br>RMS 1 2 | RMS power between cursor locations "n" and "m" is calculated and displayed in the annotation. The horizontal values of the cursors are annotated in the input field and the field directly below the input field. If two spectra are displayed, both values are calculated and annotated with the upper center annotation corresponding to the value for the upper display and the lower center annotation corresponding to the value for the lower display. |
| | Number "n"<br>(0 to 9)<br>RECALL<br>RMS 1 2 | RMS power between the current cursor location and cursor location "n" is calculated and displayed in the annotation. If two spectra are displayed, both values are calculated. |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 10a. Convert acceleration to displacement (typ) by synthetic input integration | *Number (0, 1, 2) SET ∫dt | The effect of single or double integration of the data from CHA or B (set in single ch. display) is achieved by calculations in the frequency domain after processing; most commonly used to convert acceleration data to velocity to displacement. Applie to all subsequent displays or single or dual channel frequency domain functions. (If "0" is entered, previous integration is removed. |
| 10b. Recall whether integration has been applied | RECALL ∫dt | Number displayed is number of times (2 max.) the data in CHA or B (recalled in single ch. display) has been effectively integrated. (Initialized at "0" or no integration.) |
| 11a. Convert displacement to velocity to acceleration (typ) by synthetic differentiation | *Number (0, 1, 2) SET d/dt | The effect of single (1) or double (2) differentiation of the data from CHA or CHB (single ch. display) is achieved by calculations in the frequency domain after processing; most commonly used to convert displacement data to velocity to acceleration. Applies to all subsequent displays of single or dual channel frequency domain functions. (If "0" is entered, previous differentiation is removed.) |
| 11b. Recall whether differentiation has been applied | RECALL d/dt | Number displayed is number of times (2 max.) the data has been effectively differentiated. (Initialized at "0" or no differentiation.) |
| 12a. Define 660B I/O and system parameters | Number (00 - 211) SET DEF AUX | (a) Selects Octave Processing Mode.<br>(b) Defines VIEW C display format.<br>(c) Selects output device, type of transfer, format.<br>(d) Selects format of output at cursor.<br>(e) Turns off graticule and/or cursor.<br>(f) Defines the meaning of the AUX pushbutton. See Summary of DEF AUX codes, Figure 19-3. |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 12b. Read output selected | Number (0 - 21)<br>RECALL<br>DEF AUX | Places AUX code in recall field. See Appendix C. |
| 13a. Set level of coherence, below which dual ch. freq. functions are blanked | *Sign (+ or -)<br>*Number (.000 to .999)<br>SET<br>COH BLNK | Plus sign means blanking of dual ch. functions occurs only after averaging is stopped; minus sign means that blanking occurs during data collection while averaging. Zero means no blanking. |
| 13b. Read and restore the coherence blanking level | RECALL<br>COH BLANK | The previously set blanking level is read and the blanking operation resumes per (13a.) above. (Initialized at "0" or no blanking.) |
| 13c. Turn off coherence blanking | CLEAR<br>COH BLNK | The blanking function is suppressed. The set level is retained and the function may be restored using RECALL. |
| 14a. Set an X-Y plotter rate | *Number<br>(1 to 5)<br>SET<br>PLOT RATE | 1 = very slow, 2 = slow, 3 = medium, 4 = fast, and 5 = very fast; all plot rates include automatic slow-down for large peaks to ensure faithful reproduction (PLOT in OUTPUT TYPE starts X-Y plotting of any single display.) (Initialized to 5.) |
| 14b. Recall plotter speed | RECALL<br>PLOT RATE | Places plot rate in recall field. |
| 15a. Set the range of the log display | *Number<br>(20 to 160 in 20's)<br>SET<br>DSPL DB | Lower number provides greater vertical resolution but less viewing dynamic range (Gain level shifts the range of the log display "down" for greater sensitivity or "up" for less sensitivity in 10 dB steps); number of scale marks on the vertical axis indicates display range, one mark for each 10 dB. |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 15b. Recall log display setting | RECALL<br>DSPL DB | (Initialized at "60".) |
| 16a. Read frequency relative to a reference | Number (0 to 100,000.000 or to 1.000 x $10^5$)<br>SET<br>FREQ REF | A reference frequency, identified with the cursor, is entered in Hz (directly or in scientific notation, e.g., 6.78 + 2 = 6.78 x $10^2$ = 678, after which all subsequenct frequency readings include the frequency offset. For example, to read frequency modulation directly from sideband spacing, the cursor on the carrier might be assigned "0" Hz, after which the upper side-band might read "+25 Hz" and the lower "-25 Hz". |
| 16b. Recalls the frequency offset used in relative readings | RECALL<br>FREQ REF | Reads the frequency in Hz (+ or -) of the display origin, based on SET-FREQ REF (16a above). (Initialized to "0", i.e. origin is 0 Hz.) Clear only removes the use of frequency reference, does not return it to 0. |
| 17a. Provides a reading directly in "orders of rotation" | Number (0.0001) to 99.9999)<br>SET<br>ORD REF | The order identified with the cursor is assigned a number and thereafter all readings (horizontal) will be referenced to it. For example, twice the frequency will be read as twice the set order, etc. Time domain displays will be read as "cycles" or "functions of a cycle". |
| 17b. Recalls maximum order displayed | RECALL<br>ORD REF | Reads Hz per order. |
| 18a. Activate optional digital expander (if installed) | Number (Within band)<br>SET<br>XPND | The optional digital expander is activated. The entered number is the desired center frequency of the expansion window. Refer to Options Section for further details. |

TABLE 16-1 (Con't.)

CALCULATION CONTROL KEY FUNCTIONS

| FUNCTION | SEQUENCE | DESCRIPTION |
|---|---|---|
| 18b. | CLEAR<br>SET<br>XPND | Similar to 18a. The center frequency of the expansion window is the current cursor frequency. |
| 18c. | CLEAR<br>XPND | Turn off expander and restore baseband display. |
| 19a. Window width control for optional digital expander (if installed) | Number<br>SET<br>XPND WDTH | The window width is set to the available width which includes the set number. If the entered number is negative, the expansion ratio is set directly. Refer to the Options Section for further details. |
| 19b. | RECALL<br>XPND WDTH | The entry field and the cursor horizontal field display the lower and upper bounds of the expansion window. |
| 19c. | CLEAR<br>XPND WDTH | The decimator ratio is set to its wake up state. (Decimated by 8). |
| 20. Control of the optional Data Recorder Adapter (if attached) | DISK | Refer to the Data Recorder Adapter Manual for the proper control sequences. |

TABLE 16-2

SUMMARY OF SHIFT KEY OPERATIONS

| Calculation Control Sequence | Button Label | Description |
|---|---|---|
| SHIFT 1; Blnk | EXC | No operation. |
| SHIFT 1; '•' | VER | Entry/recall field is annotated with software revision level number. |
| SHIFT 1; '0' | 660B | Entry/recall field is annotated with NICOLET 660B. |
| SHIFT 1; '1' | FLD | Entry/recall field is annotated with horizontal cursor position contents. |
| SHIFT 1; '2' | FLD | Entry/recall field is annotated with cursor amplitude upper field contents. |
| SHIFT 1; '3' | FLD | Entry recall field is annotated with lower cursor amplitude field contents. |
| SHIFT 1; '4' | CPY-> | Copy text lines into Text Field 1. (See Text Section.) |
| SHIFT 1; '5' | CPY<- | Copy text lines out of Text Field 1. (See Text Section.) |
| SHIFT 1; '6' | MOVE | Move text line. (See Text Section.) |
| SHIFT 1; '7' | MUL | Multiply Operation. |
| SHIFT 1; '8' | DIV | Divide Operation. |
| SHIFT 1; '9' | 1/X | Inverse Operation. |
| SHIFT 1; '+' | ADD | Add Operation. |
| SHIFT 1; '-' | SUB | Subtraction Operation. |
| SHIFT 1; 'EXP' | $\sqrt{\phantom{x}}$ | Square Root Operation. |

TABLE 16-2

SUMMARY OF SHIFT KEY OPERATIONS

| Calculation Control Sequence | Button Label | Description |
|---|---|---|
| SHIFT 2; '0' | 660B | No operation. |
| SHIFT 2; '•' | VER | Spectrum Calculation Control Option -8. Compile equation in Text 1. |
| SHIFT 2; Blnk | EXC | Execute a compiled equation. (See Option -8 Section). |
| SHIFT 2; '1' | FLD | Annotate the baud rate for RS232 bus last read from internal hex switches. |
| SHIFT 2; '2' | FLD | Annotate RS232 parity. |
| SHIFT 2; '3' | FLD | Annotate this device's address on the 488 bus. |
| SHIFT 2; '4' | CPY-> | Annotate whether or not a 488 bus controller is expected by 660B on the bus. See Section 19. |
| SHIFT 2; '5' | CPY<- | Single point data edit. (See Option -8 Section.) |
| SHIFT 2; '6' | MOVE | Linear interpolation between two data points. (See Option -8 Section.) |
| SHIFT 2; '7' | MUL | Multiply sign for text. |
| SHIFT 2; '8' | DIV | Divide sign for text. |
| SHIFT 2; '9' | 1/X | Calculation of damping factor. (See Option -8 Section.) |
| SHIFT 2; '+' | ADD | Text add sign, same as + without SHIFT 2 in text. |
| SHIFT 2; '-' | SUB | Text subtract sign, same as - without SHIFT 2 in text. |
| SHIFT 2; 'EXP' | $\sqrt{\phantom{x}}$ | Square root sign in text. |

In general, the data used in the calculations may be brought to the entry/recall field in any fashion available. The results are always shown in four place floating point notation, unlabelled, ready to be used as future inputs. The math results are also placed back in the math accumulator to provide the chaining capability.

SECTION 17

POWER ON CONDITIONAL STATES
(WAKE UP STATE)

17. Power On, System Reset, and Clear Panel State

In this state the 660B Spectrum Analyzer is set to the following, with NICOLET 660B appearing in the entry/recall field.

```
MODE              - DUAL 1K
FUNCTION          - INST SPEC
AVERAGE           - SUM (Averager Off, # Avg = 0)
DISPLAY          -- CH - A/B
                    FORMAT - MAG
                    MEMORY -  No lights on, no data stored
SCALES           -- AMPL - LOG
                    FREQ - LIN
OUTPUT TYPE       - CRT ONLY
AMPLITUDE UNITS - LIN, V, ABS, (PER Hz-Off)
CAPTURE CONTROL - CONT, REL, (not in HOLD, not in ARM)
Cursor Location - Midscreen
```

In addition, the CALCULATION CONTROL settings are as follows:

```
AVG N      - 16
DLY T->A   - 0
DLY A->B   - 0
V/EU       - 1 V/EU A & B
Rel        - 1
Int/Df     - Off (0)
COH BLNK   - Off (0.00)
PLOT RATE  - 5 (Fastest)
DSPL dB    - 60 dB
FREQ REF   - 0 Hz
ORD REF    - 1 Hz/Order
```

The DEF AUX settings are:

| | | |
|---|---|---|
| 0 | 1 | Output to 134A Digital Plotter over RS232 |
| 1 | 0 | 50% Redundancy, Normal Trigger |
| 2 | 0 | Graticule, Annotation, Data "On" |
| 3 | 4 | I/O Format: Binary, No Block Fill |
| 4 | 0 | (Optional) Sine Wave Cursor/Translatable Noise "OFF" |
| 5 | 5 | ASCII OUTPUT Buffer Terminator: (CR), (LF), (ETX)* *Last Buffer Only |
| 6 | 1 | Handshake "On" |
| 7 | 0 | Diagnostics Disabled |
| 8 | 0 | No Pagination |
| 9 | 0 | No Text on Display |
| 20 | 0 | Octave Mode: 1/3 Octave, 1 Pass, Normal Weighting |
| 21 | 0 | Format VIEW C as Power (10 log dB). |
| 110 | | Sine Wave At Cursor Amplitude of 1 Volt Peak |

SECTION 18

TEXT ENTRY

## 18.0 Text Entry

TEXT ENTRY enables the user to enter annotation from the front panel of the 660B without peripheral equipment. This feature adds another dimension to the report ready format available on digital plots and CRT photographs. See Figure 18-1.

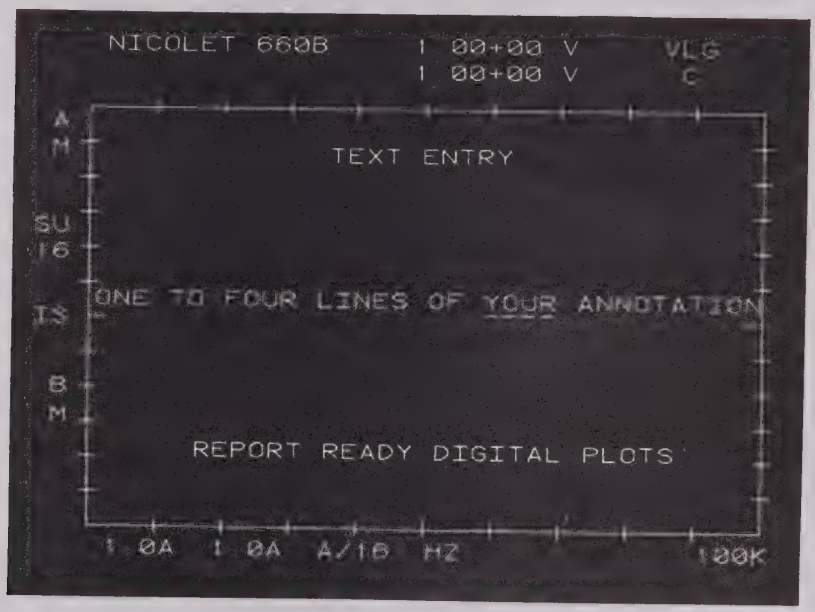



FIGURE 18-1

The TEXT mode is a mode modifier allowing all normal processes, such as averaging, to proceed while the user prepares additional explanatory annotation for the display. The TEXT mode provides four, 45 character text lines. The lines may be selected, edited, and moved anywhere on the CRT display screen.

Information may be hand entered, copied from the ENTRY/ RECALL field, or entered using either the RS232 or the IEEE-488 interface. Once the annotation is entered it may be selectively hidden form view to permit selective plotting or PANEL selective recall of specific lines.

Certain 660B front panel controls take on temporary meanings in the TEXT ENTRY mode. The controls and functions are summarized in Table 18-1.

TABLE 18-1

SUMMARY OF TEXT LINE EDITING CONTROL KEYS

| SECTION | KEY or JOYSTICK | FUNCTION |
|---|---|---|
| MODE | TEXT | ENTER/EXIT TEXT mode of operation |
| FUNCTION | TEXT 2 | SELECT TEXT EDITING mode on field #2 |
| | TEXT 3 | SELECT TEXT EDITING mode on field #3 |
| | TEXT 4 | SELECT TEXT EDITING mode on field #4 |
| TEXT ENTRY | 12 Black Keys<br>4 Blue Keys | TEXT ENTRY<br>TEXT ENTRY CONTROL |
| CALCULATION CONTROL | 15 Black Keys<br>Blue SHIFT Key | TEXT ENTRY<br>TEXT OPERATION CONTROL<br>(See COPY and MOVE functions) |
| CURSOR POSITION AND GAIN | Cursor Joystick | TEXT CHARACTER CURSOR Position control, unless MOVE function invoked, then TEXT line horizontal position control. |
| | Gain Joystick (Either) | During MOVE function, TEXT LINE vertical position control. |

1. Character Cursor Control

The character cursor is superimposed on the current character in the line, creating a reversed character image of a dark character on a light background. The cursor position is controlled by the same joystick as the data cursor, and the TEXT mode temporarily usurps the use of this control. The character cursor does not wrap-around, but stops at the extreme of the line. Whenever a new text line is selected, the character cursor appears on the left-most character of that line.

2. Text Pad with Control

The 16 keys in the TEXT ENTRY pad are used to enter alphabetic and special character text. The four blue keys control the 12 black keys. The black keys are text entry keys. Discussion of each blue control key follows.

a. Select 3rd Character

Select 3rd character key is an alternate action key used to pre-select the third character or function of the next text key. If followed by the ABC text key, the C is placed in the string. This function is automatically terminated after each text key entry.

b. Select 2nd Character

Select 2nd character key is similar in function to the select 3rd character key, however, if followed by the ABC text key the B is placed in the text string.

c. INSert

INSert key is an alternate action key used to insert characters in the middle of an existing string. During INSert, the new character is positioned at the cursor and the rest of the line is shifted to the right by one character. Characters falling off the right end are lost. Exiting TEXT or changing line selection automatically clears the INSert state.

d. RUB Out

RUB out key is used to eliminate the character at the cursor and shift the remaining characters left one position. A blank is shifted into the right-most (45th) position.

e. Select 3rd character, followed by RUB, places a NULL (internal end of character string indicator) at the position of the cursor. As long as the cursor is on this location, it is not interpreted as a NULL end of character string. Therefore, the remainder of the line can still be viewed. Moving

the cursor off this point allows the NULL to take effect. The NULL is used to truncate a line for digital plotters preventing them from plotting the remaining blanks. Also, the NULL may be used to temporarily hide the remaining text line and permit multiple pre-stored texts to be moved up quickly and conveniently.

3. Numeric Pad

The black CALCULATION CONTROL keys are used to enter the indicated character into a text line. The EXP black key serves to copy the contents of the 14 character ENTRY/RECALL field into the text line. All SHIFTed black key functions retain their identity. The CPY<- (SHIFT 1:4) and CPY-> (SHIFT 1:5) are described in the line copying section. The move (SHIFT 1:6) is described in the line positioning section. Note, that the CALCULATION CONTROL blue and white keys retain their function, such as RECALL: AVG N or CLEAR: DLY T->A. The black keys numeric entry function is used for text entry. SHIFT 2: 7, 8, and EXP enter text X, /, or $\sqrt{\ }$ ,respectively.

4. Line Copying

The complete 45 character line copying is to and from text line #1. This enables the user to define a common heading and copy it into other text lines for minor modification. Copying into a text line from line #1 is accomplished by selecting the destination text line (2, 3, or 4), CPY<- (CALCULATION CONTROL SHIFT 1:4). Copying from a text line to line #1 is accomplished by selecting the source text line (2, 3, or 4), CPY-> (CALCULATION CONTROL SHIFT 1:5).

5. Text Line Positioning

Text lines may be positioned anywhere on the CRT display. After selecting the text line to be moved, issue a MOVE (CALCULATION CONTROL SHIFT 1:6). Horizontal motion is in 1/2 character steps controlled by the CURSOR POSITION joystick, while vertical motion is in 1/2 character steps controlled by either GAIN joystick. The joystick control over line position is revoked as soon as another editing operation is performed, such as INS. The line remains where positioned.

6. Selective Text Viewing

The user is provided with the ability to display one text line, all text lines, or none of the text lines. Text line display is controlled by the 90 series DEFine AUXiliary:

| | |
|---|---|
| 90 | No Text Displayed (Power up Default) |
| 91 | Text Line #1 Only |
| 92 | Text Line #2 Only |
| 93 | Text Line #3 Only |
| 94 | Text Line #4 Only |
| 95 | All Text Lines Displayed |

Consistent with all DEF AUX codes, this code is stored and recalled with PANEL, and DISPLAY MEMORY status. Note, the characters and position of the text lines are not stored; the display selection code (DEF AUX) is stored. This allows the user to view pre-stored lines via recalled panels.

When TEXT mode is entered, 95 DEF AUX is invoked. The current 90 series DEF AUX is saved and re-instated when TEXT mode is exited.

7. Exercise

The objective is to position the 4 lines, one above the other, in the upper-left hand corner of the data area within the graticule. Each line is to have its line number as its first character.

a. Select TEXT mode: Depress the blue TEXT mode button.
Note the character cursor appearing in the extreme upper-left corner of the CRT.
This is TEXT LINE #1.

b. Place a 1 in the first character of LINE #1: Depress CALCULATION CONTROL 1. See Figure 18-2.

c. Move TEXT LINE #1 within graticule: CALCULATION CONTROL Sequence SHIFT 1:6.
Note the CALCULATION CONTROL Sequence SHIFT 1:6 is referred to as MOVE in the remainder of the example.
Also note that the character cursor moved to the beginning of LINE #1.
Deflect the CURSOR joystick right or left for horizontal alignment.
Deflect either GAIN joystick up or down for vertical alignment.
Move the TEXT line about until the 1 appears just inside the graticule. See Figure 18-3.

d. SELECT TEXT LINE #2: Depress FUNCTION section blue key marked TEXT 2.
The LED will indicate the completion of the selection.
LINE #1 will remain where it was positioned.
The character cursor will appear as the 1st character in LINE #2.

e. Place a 2 in LINE #2: As in b (above) depress:
CALCULATION CONTROL 2. See Figure 18-4.

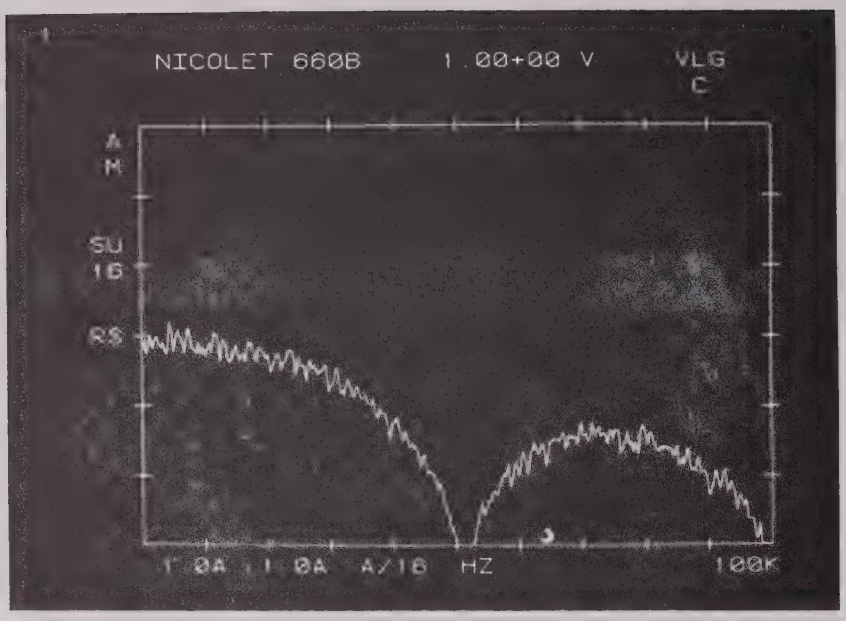



FIGURE 18-2

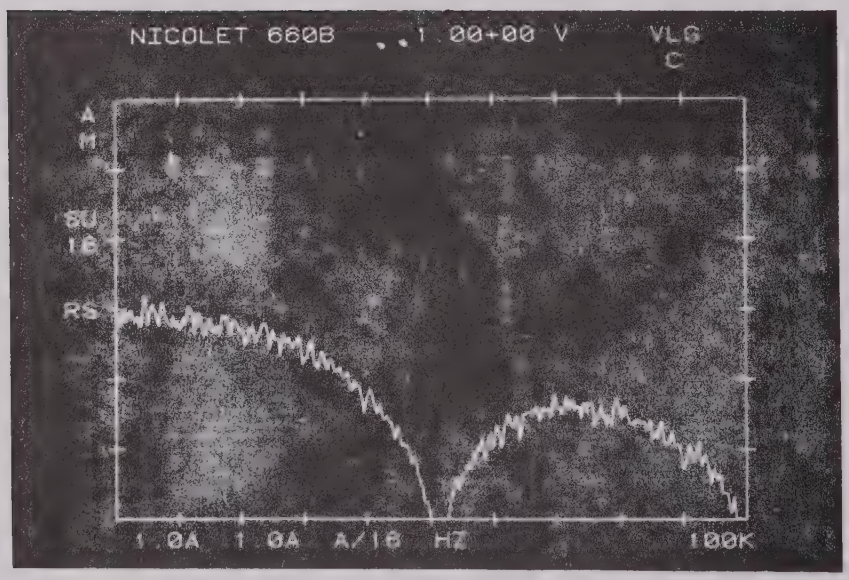



FIGURE 18-3

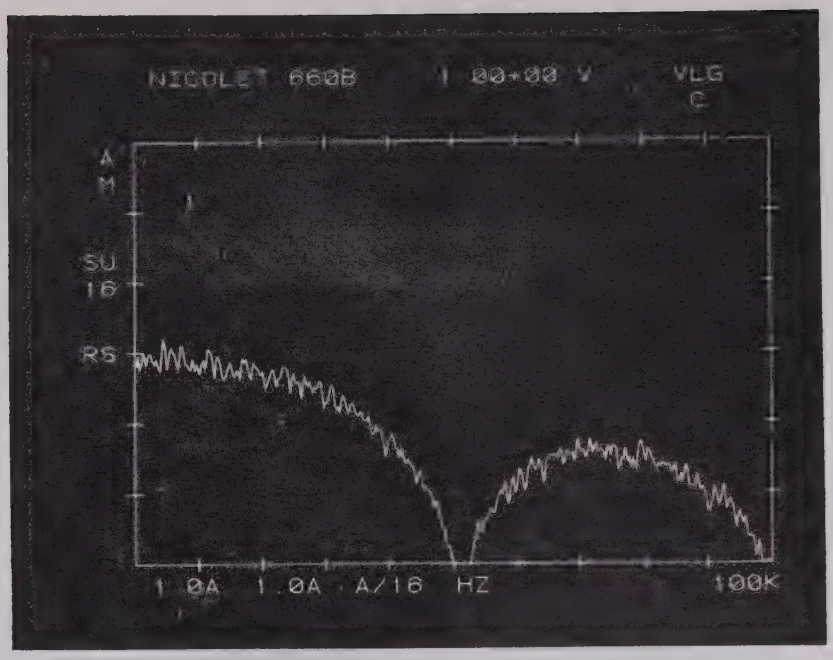



FIGURE 18-4

f. Move TEXT LINE #2 to below LINE #1: As in step c the CALCULATION CONTROL Sequence for MOVE will cause the character cursor to appear at the beginning of LINE #2, highlighting the 2 just entered.
With the joystick controls, move this line to just below LINE #1.
Notice that movement resolution is in 1/2 width and height. See Figure 18-5.

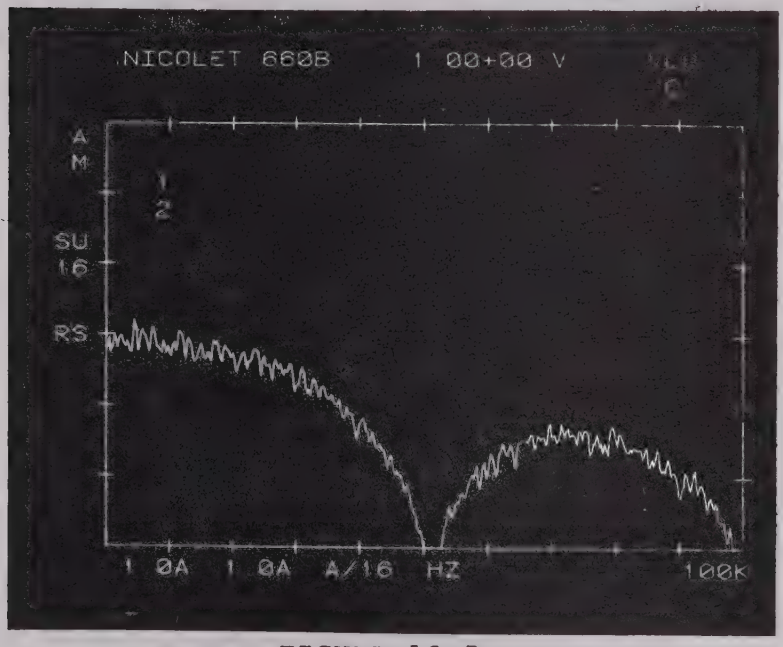



FIGURE 18-5

g. Now that the selection, single number entry, and movement is understood, repeat the process for lines #3 and #4.

h. At this point the 4 lines should be neatly stacked one over the other just within the graticule.

i. Copy ENTRY/RECALL line contents into TEXT LINE #2. See Figure 18-6.

   1. Select FUNCTION: TEXT 2
   2. Move character cursor one step right with CURSOR joystick.
   3. Copy ENTRY/RECALL by depressing CALCULATION CONTROL: EXP.

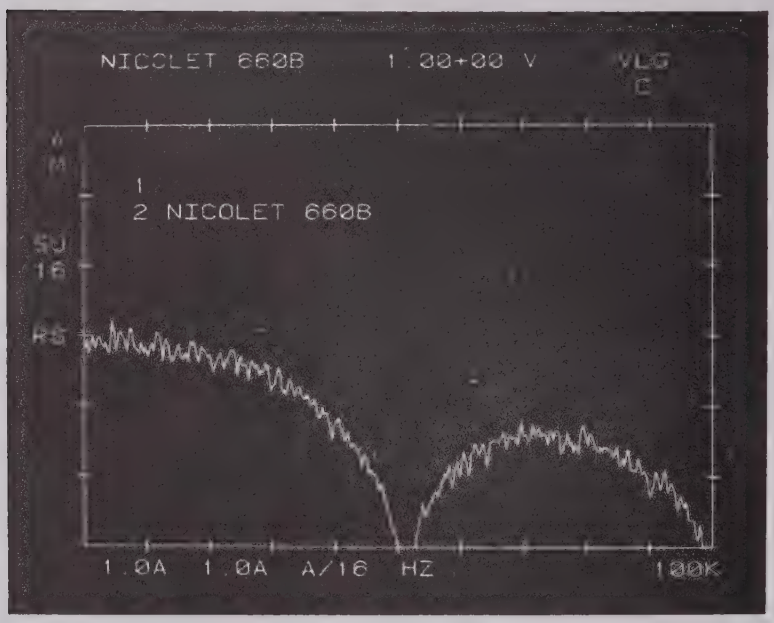



FIGURE 18-6

j. Insert ENTRY/RECALL field contents into TEXT LINE #2, See Figure 18-7. CONTROL Sequence: RECALL; AVGN.

   1. Fill ENTRY/RECALL field with something new, such as the CALCULATION CONTROL Sequence: RECALL; AVGN.
   2. Reposition character cursor between the 2 and the rest of the TEXT line.
   3. Depress INSert in the TEXT ENTRY control section. Blue key, LED should light.
   4. Copy ENTRY/RECALL field by depressing CALCULATION CONTROL: EXP. Notice the original TEXT copied from the ENTRY/ RECALL field moved to the right and the new text inserted.

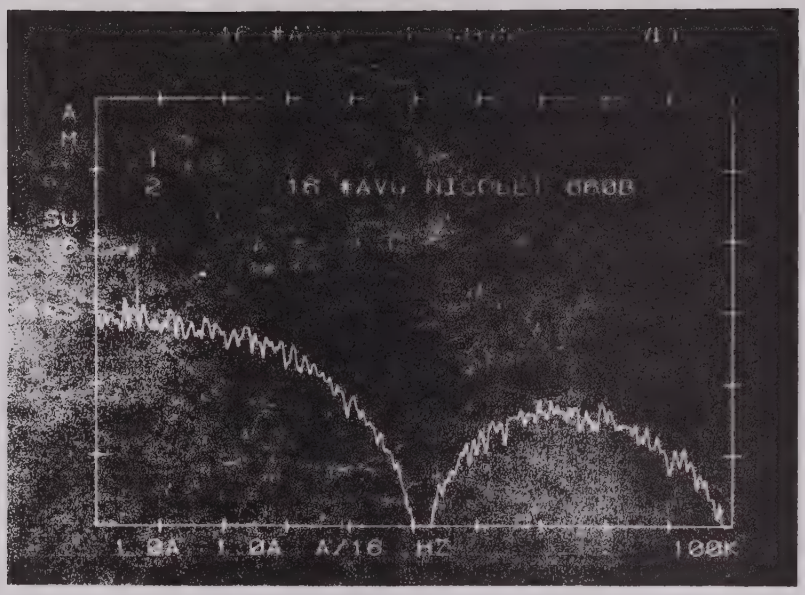



FIGURE 18-7

k. EXIT TEXT MODE: Depress TEXT MODE key thereby exiting TEXT MODE, and extinguishing the LED. Note that the TEXT lines disappeared. When TEXT mode was entered no lines were selected to view and now that condition is restored.

l. Observe the effects of the following on the TEXT.

```
91; SET; DEF AUX
92; SET; DEF AUX
93; SET; DEF AUX
94; SET; DEF AUX
95; SET; DEF AUX
90; SET; DEF AUX
```

SECTION 19

# DIGITAL INTERFACES TO THE 660B

## 19.1 Available Interfaces

### A. Introduction

In order to allow remote control of the 660B and enable the user to input and output data, three digital interfaces are provided on the back panel. These interfaces and the corresponding connector numbers follow:

| | | |
|---|---|---|
| 1. | IEEE-488 | J111 |
| 2. | RS232-C | J112 |
| 3. | Parallel A/D | J113 |

The data which is available via these interfaces includes, but is not limited to, digital time domain data, frequency domain data, averaged data, and front panel settings. A brief description of the interfaces is presented with in-depth examination of each interface following in a later section.

### B. IEEE-488 (1978)

The IEEE-488 interface can be used both to control the operation of the 660B and to input or output data. The IEEE-488 interface may or may not have a bus controller. This must be determined first, since the setting of the hex switches (Section 19-2) followed by a SYStem ReSeT is involved. If no controller is present on the IEEE-488 bus, but use of the interface is desired, non-controller use of the bus may be affected via a switch setting. In this mode, the 660B powers up as a listener on the bus, making itself a talker when commanded to output data, and reverting to the listener state upon completion of the output. Hence, control of the 660B and data transfer can be accomplished without the use of an IEEE-488 bus controller.

### C. RS232-C

The 660B implements EIA RS232-C. To facilitate interconnect to both modems and terminals, the TD, RD connections emulate a modem and the RTS, CTS connections emulate a terminal. Most terminals may be connected with a standard one-to-one cable. Reversing the cable connections to TD, RD gives full terminal emulation. Reversing the cable connections to RTS, CTS gives full modem emulation. The user can select the desired bit rate

(from 110 baud to 9600 baud) and the parity (odd, even, or none) via hexadecimal switch settings. As with the IEEE-488 interface, the RS232-C interface can control the 660B and transfer data into and out of internal memory.

D. Parallel A/D

The 660B uses 12-bit, 2.5 microsecond conversion time, analog-to-digital converters in the A and B input channels. Data from the converters is provided at the parallel A/D interface connector in two's complement, fixed point format, with each word to be interpreted as a fraction of the full scale selected by the front panel rotary switches. Alternatively, the internal A/D converter may be effectively replaced by an external source by providing data in the above format to the parallel A/D connector. This allows the 660B to analyze user-generated digital time domain data.

## 19.2 Using the Interfaces

### A. Selecting Interface Parameters

In order to provide as much flexibility as possible when using the 660B interfaces, many of the interface parameters are user selectable. Some parameters are selected in hardware via a switch setting; some are under program control and can be set using the DEFine AUX pushbutton in the CALCULATION CONTROL group. The available parameters and the manner in which selection is made are summarized in this section. Additional information about each parameter can be found in the section discussing the interface concepts related to that parameter.

Note, most of the information in the following sections describes the RS232-C and IEEE-488 interfaces. The parallel A/D interface is discussed separately.

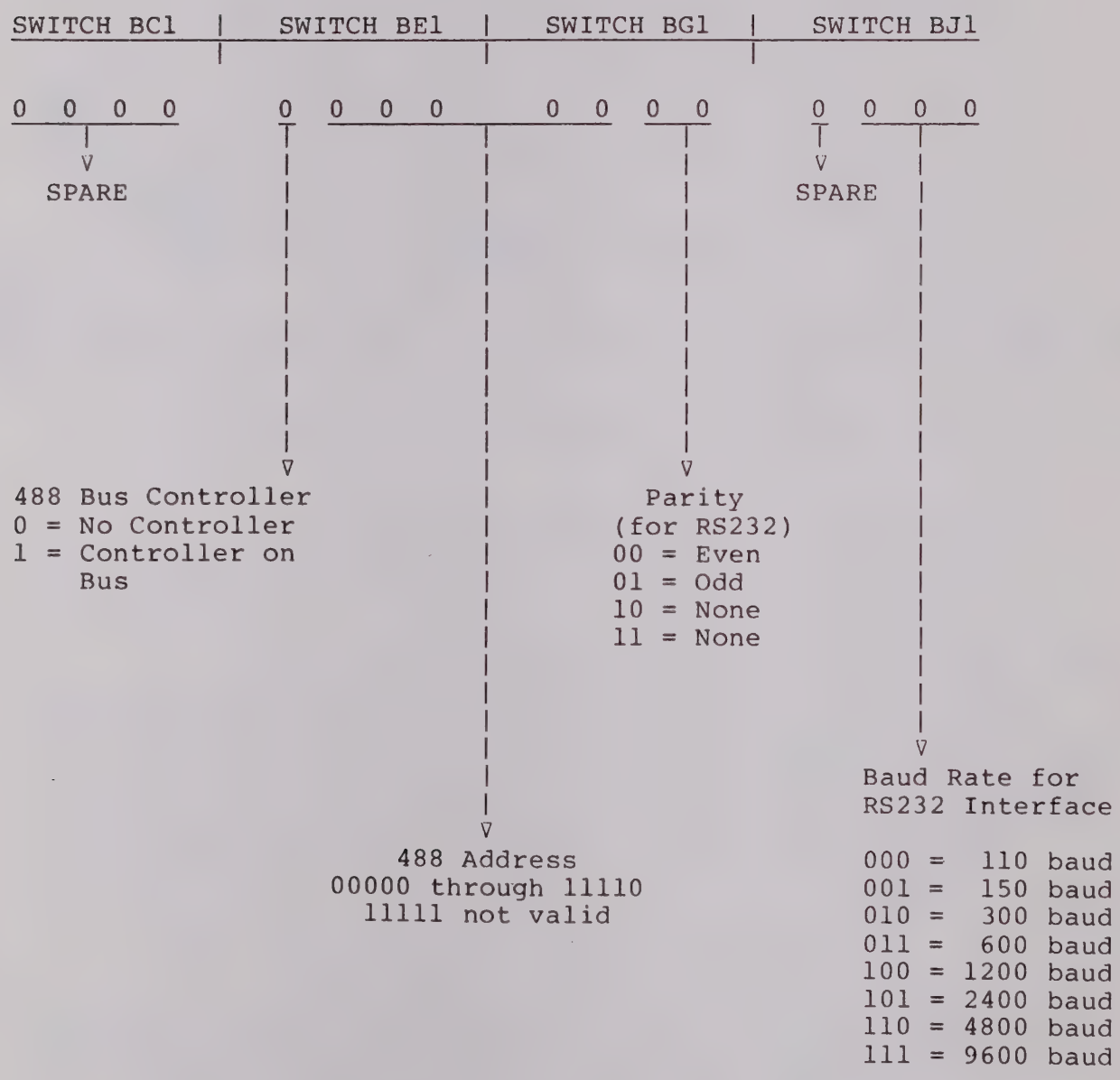
#### 1. Switch Selectable Parameters

The interface parameters which are essential to the operation of the RS232-C and IEEE-488 interfaces are controlled by switch settings. The interface parameters must be matched to the parameters of the interface in use. If the parameters are not matched, errors will occur either in the 660B or the external device.

Figure 19-1 indicates the interface parameters which are switch selectable. These switches are rotary hexadecimal switches and are located on the Executive Board as shown in Figure 19-2. Note, the unusual switch numbering scheme is based on the component locating method used on the Executive Board.

FIGURE 19-1

HEXADECIMAL SWITCH SETTINGS



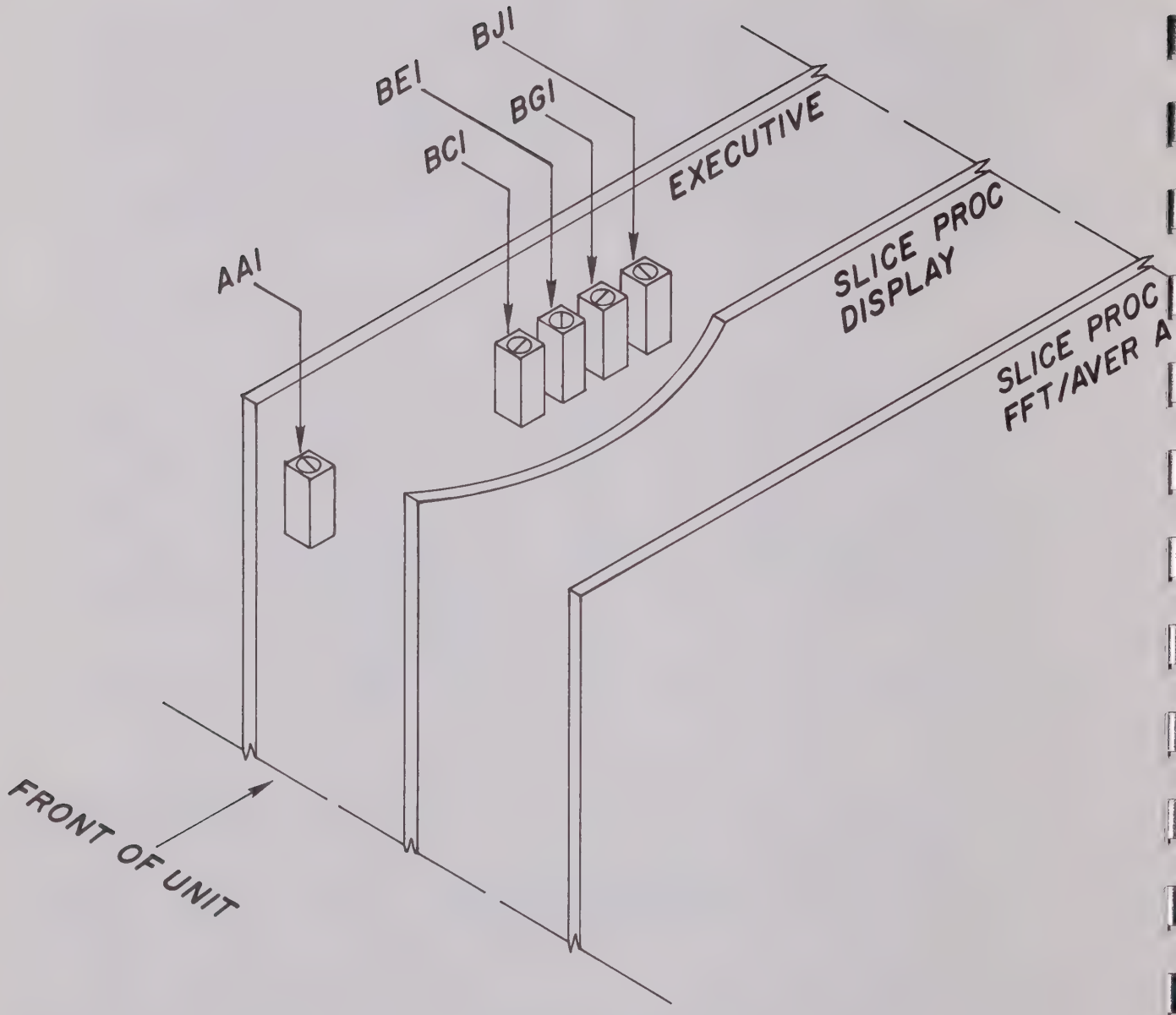



FIGURE 19-2. LOCATION OF SWITCHES ON EXECUTIVE BOARD

For example, switch BC1 is located at Section B, Column C, and Row 1. Each switch controls the value of 4 bits of parameter information. To select the correct switch setting, determine the value of each parameter bit (0 or 1) and add together the weighted value of the bits which are 1. The weights are 8, 4, 2, or 1 as shown in Figure 19-1. The weighted sum equals the setting of the switch except that sums of 10 = A, 11 = B, 12 = C, 13 = D, 14 = E, and 15 = F.

For example, if the following parameters are desired:

a. 488 Address = 7 = 00111,
b. 488 bus controller on the IEEE-488, and
c. the RS232-C interface should operate at 600 baud with even parity,

then the bit values from Figure 19-1 are as follows:

| SPARE | 488 CONTROLLER | 488 ADDRESS | PARITY | SPARE | BAUD RATE |
|---|---|---|---|---|---|
| 0000 | 1 | 00111 | 00 | 0 | 011 |

Grouping these bits 4 at a time, since there are 4 bits per switch, gives 0000 1001 1100 and 0011. The weighted sum of these bits is : 0 9 12 3. Since 12 = C, the switch settings are BC1 = 0, BE1 = 9, BG1 = C, and BJ1 = 3.

The parameters selected by the hexadecimal switches are fundamental to the operation of the RS232-C and IEEE-488 interfaces. The switches are interrogated only on power up and after the SYS RST (system reset) pushbutton has been depressed. If any switch setting is changed while the 660B is on, the SYS RST pushbutton must be depressed for the desired parameters to be selected. The parameters pertaining to the RS232-C and IEEE-488 interfaces are discussed in the sections describing each interface.

2. DEFine AUXiliary Selectable Parameters

Another group of interface parameters can be selected in conjunction with the DEF AUX pushbutton. The parameters are summarized in Figure 19-3. The general format of a DEF AUX code is a two-digit number (GP). The first digit (G) determines the group or DEF AUX series. The second digit (P) selects a function within that group.

To set any of the functions indicated in Figure 19-3, enter the sequence: GP SET DEF AUX, where GP is the DEF AUX code corresponding to the parameter desired. The 660B will acknowledge the setting of a DEF AUX function by displaying the DEF AUX code followed by the group abbreviation in the entry field shown in Figure 19-3. For example, if the sequence: 51 SET DEF AUX is entered, the entry field will display: 51 OUTT. If the number entered is not a valid DEF AUX code, an error message will be displayed in the entry field. This error message will display the valid range of codes in inverted characters. For example, if the sequence: 38 SET DEF AUX is entered, the entry field will display: "30 > 35" indicating the allowable range of values for the 30 series of DEF AUX.

To determine the current state of any DEF AUX selectable parameter, enter the sequence: (G) RECALL DEF AUX where G is the group number associated with the DEF AUX parameter. The 660B entry field will display the current setting of that group followed by the group abbreviation. For example, if the current 30 series of DEF AUX is 34 (I/O format is binary with no blockfill) and the sequence: 3 RECALL DEF AUX is entered, the entry field will display: 34 I/OF.

On power up, after SYS RST or after entering the sequence: CLEAR PaNeL, the DEF AUX groups are set to the default states indicated for each group in Figure 19-3. A more detailed discussion of the functions selectable via the DEF AUX pushbutton may be found in Figure 19-3.

| |
|---|
| NOTE: THE SETTING OF THE DEF AUX CODES FOR ALL DEF AUX GROUPS AS WELL AS THE FRONT PANEL SETTINGS ARE STORED WHEN THE SEQUENCE: NUMBER (1 THROUGH 9) SET PANEL IS ENTERED. THIS PROVIDES AN EASY METHOD OF SAVING FREQUENTLY DESIRED I/O PARAMETERS. |

B. Types of Information

Two types of information can be transferred over the the interfaces to the 660B. The first type consists of commands used to control the operation of the 660B. The command set allows the user to emulate the front panel via either the RS232-C or the IEEE-488 interface. Certain commands, not available on the front panel, are available to the user when controlling the 660B with an interface, for example, a front panel lock out command.

FIGURE 19-3

SUMMARY OF DEFINE AUXILIARY SERIES

SPECIAL OUTPUT USING AUX BUTTON — ABBR. = AUX0

| Function | DEFine AUX | Comments |
|---|---|---|
| Rest at cursor mode for analog plotter | 00 | |
| 134A or 136A Plotter output over RS232-C Interface | 01 | Default |
| 134A or 136A Plotter output over IEEE-488 Interface | 02 | For use by the 160 Data Recorder Adapter |
| Cursor fields output over RS232-C Interface | 03 | The 50 series of DEFine AUX is used to determine the separators between cursor fields |
| Cursor fields output over the IEEE-488 Interface | 04 | |

NOTE: LEADING ZERO IS OPTIONAL.

BLOCK SYNC AND REDUNDANCY — ABBR. = REDN

| Function | DEFine AUX | Comments |
|---|---|---|
| Normal triggering with 50% redundancy | 10 | Default |
| Normal triggering with 0% redundancy | 11 | |
| Block sync triggering with 50% redundancy | 12 | |
| Block sync triggering with 0% redundancy | 13 | |

FIGURE 19-3 (Con't)

SUMMARY OF DEFINE AUXILIARY SERIES

| ANNOTATION & GRATICULE | | ABBR. = ANGR |
|---|---|---|
| Function | DEFine AUX | Comments |
| All On | 20 | Default |
| Graticule Off | 21 | |
| Annotation Off | 22 | Includes cursor fields |
| Annotation & Graticule Off | 23 | |
| Data Off | 24 | |
| Data & Graticule Off | 25 | |
| Data & Annotation Off | 26 | |
| All Off | 27 | |

NOTE: ENTRY FIELD CAN NOT BE TURNED OFF.

| I/O FORMAT | | ABBR. = I/OF |
|---|---|---|
| Function | DEFine AUX | Comments |
| Decimal ASCII format | 30 | 3 formats dependent on internal format |
| Decimal ASCII with blank blockfill on output† | 31 | 8-bit integers = 4 characters (0 to 255); 16-bit integers = 8 characters (-32768 to +32767); 3-byte floating point = 12 characters (X.XXX±EE) |
| Hexadecimal ASCII format | 32 | 2 characters per byte |
| Hexadecimal ASCII with blank blockfill | 33 | |
| Binary Format | 34 | Default format |
| Binary Format with null blockfill | 35 | Block fill byte is nulls instead of blanks |
| S1 Format (Output Only) | 36 | For NSC Test Dept. ONLY |
| S1 Format with S9 at End (Output Only) | 37 | For NSC Test Dept. ONLY |

†THE 660B REQUIRES ALL INPUT TO BE BLOCK FILLED.

FIGURE 19-3 (Con't.)

SUMMARY OF DEFINE AUXILIARY SERIES

SINE WAVE AT CURSOR CONTROL — ABBR. = SINE

| Function | DEFine AUX | Comments |
|---|---|---|
| Off | 40 | |
| Sine Wave At Cursor | 41 | All functions work with DRT on or off |
| Pseudo-Random Noise | 42 | |
| Periodic Noise | 43 | |

OUTPUT BLOCK TERMINATORS — ABBR. = OUTT

| Function | DEFine AUX | Comments |
|---|---|---|
| No terminators | 50 | Terminators are not included in the block size on the output. On input, no terminators are allowed and the setting of the 50 series DEFine AUX is ignored. However, if the input format is ASCII, an EOT will terminate the input. |
| EOT after last block | 51 | |
| Carriage return after each block | 52 | |
| Carriage return after each block plus EOT after the last carriage return | 53 | |
| Carriage return/line feed after each block | 54 | Terminators can only be applied if the format is ASCII |
| Carriage return/line feed after each block plus EOT after last carriage return/line feed | 55 | Default |

SOFTWARE HANDSHAKE FOR OUTPUT OVER RS232-C INTERFACE — ABBR. = HSHR

| Function | DEFine AUX | Comments |
|---|---|---|
| No handshake required | 60 | |
| 660B waits for a ready byte (CNTRL/V) before outputting each block | 61 | 61 is the default condition for the 60 series of DEFine AUX |

FIGURE 19-3 (Con't.)

SUMMARY OF DEFINE AUXILIARY SERIES

| DIAGNOSTICS | | ABBR. = DIAG |
|---|---|---|
| Function | DEFine AUX | Comments |
| Normal | 70 | Default |
| For NSC Test Dept. ONLY | | Changing this DEF AUX setting could drastically affect the operation of the 660B |

| MODEL 136A DIGITAL PLOTTING ADAPTER PAGINATION | | ABBR. = PAGE |
|---|---|---|
| Function | DEFine AUX | Comments |
| No pagination | 80 | Default |
| 1-9 Pages after Plot | 81-89 | |

| TEXT | | ABBR. = TEXT |
|---|---|---|
| Function | DEFine AUX | Comments |
| Text | 90 | Default, text off |
| | 91 | Line 1 on display |
| | 92 | Line 2 on display |
| | 93 | Line 3 on display |
| | 94 | Line 4 on display |
| | 95 | All four lines on display |

| SINE WAVE AT CURSOR AMPLITUDE | | ABBR. = AMPL |
|---|---|---|
| Function | DEFine AUX | Comments |
| Amplitudes of all outputs from Sine Wave at Cursor Option | 100-199 | Peak Voltage = (N - 100) * 100 mv<br>Default H = 100 ... 1 volt peak |

FIGURE 19-3 (Con't.)

SUMMARY OF DEFINE AUXILIARY SERIES

OCTAVE — ABBR. = OCTT

| Function | DEFine AUX | Comments |
|---|---|---|
| 1/3, 1 Pass | 200 | |
| 1/3, 2 Pass | 201 | |
| 1/1, 1 Pass | 202 | |
| 1/1, 2 Pass | 203 | |
| 1/3, 1 Pass A-Weighting | 204 | |
| 1/3, 2 Pass A-Weighting | 205 | |
| 1/1, 1 Pass A-Weighting | 206 | |
| 1/1, 2 Pass A-Weighting | 207 | |

VIEW C — ABBR. = CMdB

| Function | DEFine AUX | Comments |
|---|---|---|
| Power Display | 210 | 10 log Vc |
| Voltage Display | 211 | 20 log Vc |

The second type of information transferrable over the RS232-C or IEEE-488 interface is information from or to one of the 660B internal data buffers. The data buffers allow the user to access data at specific points in the processing flow of the 660B. For example, processed digital time data (SIG ENH Mode), and unscaled averaged frequency domain data (1K, 2K FFT Mode), can be output or input. Option -8 permits scaled data to be input to and output from the Complex Math buffer C. Control settings of the 660B can also be output for use by an external device. This enables the user to replicate the front panel settings in future operations. The exact nature and format of each type is covered in Section 19.3, Paragraph B.

C. Controlling the 660B

1. Emulating the Front Panel

In the normal operating mode, the user operates the 660B via the front panel. When a button is depressed or a switch position changed, the front panel communicates the user's request to the system executive using a one or two character code in ASCII format. The system executive acts based on the character code received. The character transmission from the front panel to the system executive is internal and transparent to the user.

The front panel is not the sole command input. Additional ports for command characters are the RS232-C and IEEE-488 interfaces. Once the executive receives a command from either the front panel or over an interface, the source of command is retained. The executive performs the actions corresponding to the command code and returns an acknowledge to the source of command. See Figure 19-4.

The code associated with each front panel switch is indicated in Figure 19-5. The code is located in the upper right-hand corner of each pushbutton; the code for each fixed switch and joystick position is shown adjacent to the label for that position.

A discussion follows of the commands generated by the pushbuttons and fixed switches on the front panel and the corresponding actions of the system executive upon receiving these commands. Having established the equivalence of commands issued from the front panel with those issued over the RS232-C and IEEE-488 interfaces, any statement concerning a particular pushbutton on the front panel, holds true for command codes issued over the interface.

## COMMAND INPUTS TO THE EXECUTIVE

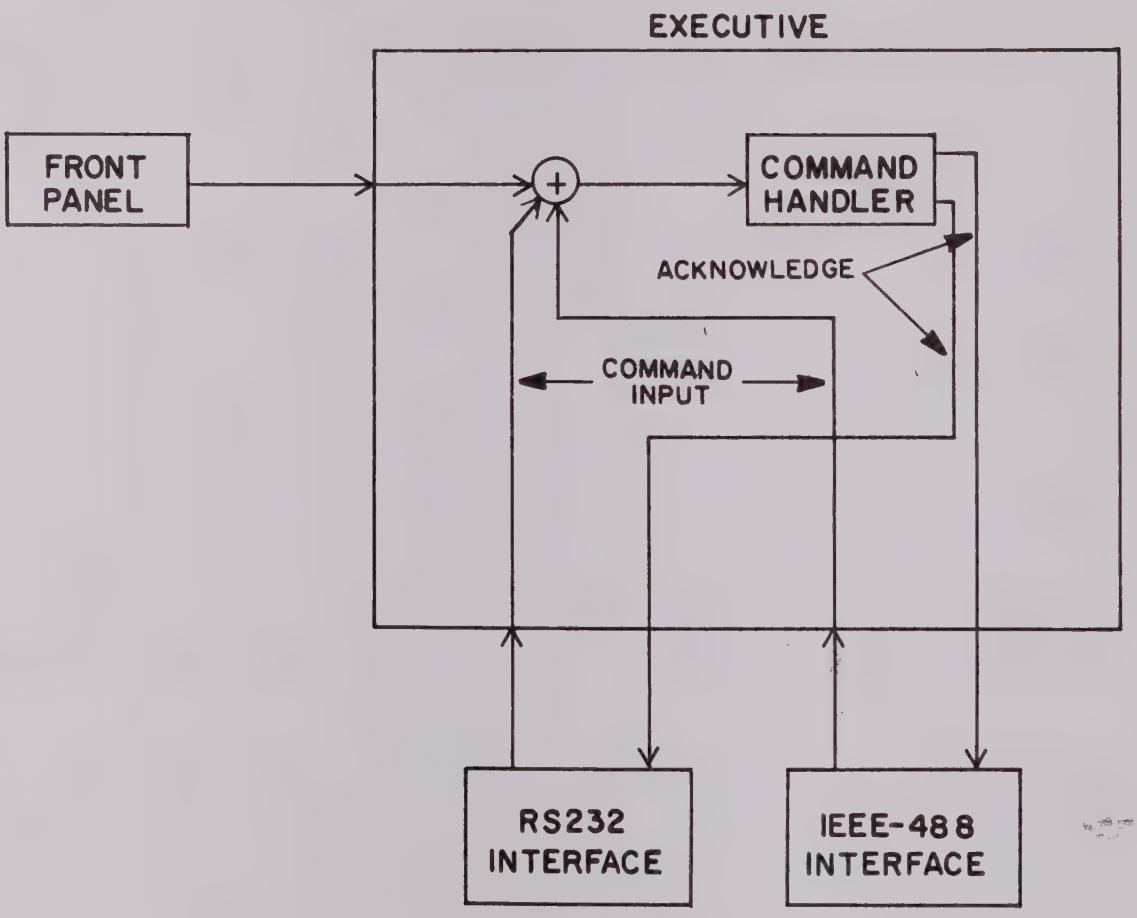



FIGURE 19-4. COMMAND INPUTS TO THE EXECUTIVE

a. The commands received by the system executive are checked in the same manner regardless of their source. For example, issuing an F2 over an interface while in the CHA 2K FFT mode will cause the error message MUST VIEW A to be displayed in inverted characters in the entry field and, a NAK will be returned if the interface was RS232 or if the interface was IEEE-488, the serial poll register will be updated with NAK status.

b. The command codes associated with pushbuttons astericked in Figure 19-6 complement the state controlled by that pushbutton. When using the interfaces, additional commands are provided for selecting a particular state. See Section 19.2, Paragraph C.2., entitled "Additional Remote Commands."

c. The commands associated with each fixed switch, (those switches which are not pushbuttons and not one of the three joysticks), are issued by the front panel only when the switch position changes. This allows the code for a desired switch setting to be sent using an interface, without the front panel overriding the information with a current switch setting. However, if a switch setting on the front panel is changed, the new position will override the setting commanded by an interface. For example, if the FREQUENCY RANGE rotary selector is set to 200 Hz and the code QE (50,000 Hz) is issued over an interface, the 660B will enter the 50,000 Hz range. If the FREQUENCY RANGE rotary selector is then set to 100 Hz, the 660B will enter that range. This front panel override of the setting issued over an interface can be prevented by effecting the front panel lock out feature, see Section 19.2, Paragraph C.2, entitled "Additional Remote Commands."

d. There are three joysticks on the front panel of the 660B, namely, GAIN--UPPER OR SINGLE, GAIN LOWER, and CURSOR POSITION--LEFT or RIGHT. Each is actually a three-position joystick with a neutral center position. The term neutral means that no action is taken by the 660B when the joystick is in the neutral center position. When a joystick is moved to either extreme, the appropriate command is issued. The joysticks differ from the fixed switches in that they incorporate a timer which reissues the current joystick position command if the joystick is not returned to the neutral position within a prescribed delay period. The CURSOR POSITION joystick has the additional distinction that when the stick is first moved, the cursor moves a single cursor cell position in the direction indicated. However, when the timer reissues the cursor movement command, the larger stepsize command is used.

FIGURE 19-6

REMOTE CONTROL COMMANDS

NOTE: This figure contains only those remote control commands which are equivalent to front panel pushbuttons. Additional commands are contained in Figure 19-7.

MODE

| | | |
|---|---|---|
| SIG ENH | Signal Enhancement | M0 |
| CHA 2K (2K CHA FFT)† | 2K Channel A FFT | M1 |
| DUAL 1K (1K CHA-B FFT) | 1K Channel A-B FFT | M2 |
| CORR | Correlation | M3 |
| PROB | Probability | M4 |
| TEXT | Enter or Exit TEXT Mode | M5 |
| OCTAVE | Enter or Exit OCTAVE | M6 |

FUNCTION

| | | |
|---|---|---|
| INPT TIME (INPUT TIME) | Input Time | J0 |
| AVG TIME | Averaged Time | J1 |
| INST SPEC | Instantaneous Spectrum | J4 |
| RMS SPEC | Averaged RMS Spectrum | J5 |
| PWR SPEC (POWER SPEC) | Averaged Power Spectrum | J6 |
| X SPEC (CROSS SPEC) | Averaged Cross Spectrum | J2 |
| TF | Transfer Function | J3 |
| COH | Coherence Function | JB |
| IMP RESP (IMPUL RESP) | Impulse Response | J9 |
| TM | Transmissibility | JA |
| COP | Coherent Output Power | J7 |
| X CORR (CROSS CORR) | Cross Correlation | JD |
| AUTO CORR | Auto Correlation | JC |
| CDF (CUM DIST) | Cumulative Distribution Function | K1 |
| PDF (PROB DEN) | Probability Density Function | K0 |
| TEXT 2 | Text Line 2 | K9 |
| TEXT 3 | Text Line 3 | KA |
| TEXT 4 | Text Line 4 | KC |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

AVERAGE

| | | |
|---|---|---|
| SUM | Summation Averaging | V0 |
| START | Start | V8 |
| DIFF | Difference Averaging | V1 |
| STOP | Stop | V9 |
| EX (EXP) | Exponential Averaging | V2 |
| CONT | Continue | VA |
| PEAK | Peak Detect Averaging | V3 |
| SWEEP | Sweep Averaging | V4 |
| TRAN (TRANS) | Transient Averaging | V5 |

DISPLAY

CH

| | | |
|---|---|---|
| | Channel A | F1 |
| A | Channel B | F2 |
| B | Channel A and B | F3 |
| A B | | |

FORMAT

| | | |
|---|---|---|
| NYQ | Nyquist | F7 |
| REAL | Real | F4 |
| IMAG | Imaginary | F5 |
| R I | Real and Imaginary | F6 |
| MAG | Magnitude | F8 |
| Ø (PHASE) | Phase | F9 |
| Ø MAG (PHASE MAG) | Phase and Magnitude | FA |

MEMORY

| | | |
|---|---|---|
| STO D (STORE)* | Store | E0 |
| COMP D* | Compare | E2 |
| RCL D (RECALL)* | Recall | E1 |
| EQL D (EQL TF/TM)* | Equalize Transfer Function or Transmissibility | E3 |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

| | | |
|---|---|---|
| **AMPLITUDE UNITS (CURSOR READS)** | | |
| dB/LIN* | Complement Current State | U0 |
| V/EU* | Complement Current State | U1 |
| ABS/REL* | Complement Current State | U2 |
| PER Hz* | Complement Current State | U3 |
| **CURSOR POSITION** | | |
| LEFT | Small Step | I0 |
| RIGHT | Small Step | I1 |
| LEFT | Large Step | I8 |
| RIGHT | Large Step | I9 |
| **CURSOR TYPE** | | |
| HARMONIC | | H3 |
| SINGLE | | H1 |
| OFF | | H0 |
| **GAIN** | | |
| | Upper Increase | I2 |
| | Upper Decrease | I3 |
| | Lower Increase | I4 |
| | Lower Decrease | I5 |
| **FREQ READS** | | |
| Hz | | H4 |
| CPM | | H5 |
| ORDERS | | H6 |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

| | | |
|---|---|---|
| **SCALES** | | |
| AMPL LOG/LIN* | Vertical (Amplitude) Axis Logarithmic/Linear | G0 |
| FREQ LOG/LIN* | Horizontal (Frequency) Axis Logarithmic/Linear | G1 |
| **OUTPUT TYPE** | | |
| PLOT* | | Ø0 |
| PLOT CAL (PLOT SET-UP)* | | Ø1 |
| AUX* | | Ø2 |
| CRT ONLY | | Ø3 |
| **CALCULATION CONTROL** | | |
| + | | + |
| 7 | | 7 |
| 4 | | 4 |
| 1 | | 1 |
| 0 | | 0 |
| - | | - |
| 8 | | 8 |
| 5 | | 5 |
| 2 | | 2 |
| . | Exponent | . |
| EXP | | X |
| 9 | | 9 |
| 6 | | 6 |
| 3 | | 3 |
| SHIFT 1 | | * |
| SET STORE | | S |
| RECALL | | R |
| SHIFT 2 | | , |
| CLEAR | | Z |
| AVG N | Number of Averages | W0 |
| PNL (PANEL) | Panel Manipulation | W1 |
| ∫dt | Integrate | W2 |
| COH BLNK | Coherence Blanking | W3 |
| KEY XPND or XPND | Key Expand or Expand | W4 |

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

CALCULATION CONTROL (Con't.)

| | | |
|---|---|---|
| DLY T->A (DELAY T->A) | Delay from Trigger to Channel A | W5 |
| CUR LOC | Cursor Location | W6 |
| d/dt | Differentiate | W7 |
| PLOT RATE | X-Y Plotter Speed Control | W8 |
| CUR XPND or XPND WDTH | Cursor Expand or Expand Width | W9 |
| DLY A->B (DELAY A->B) | Delay from Channel A to Channel B | Y0 |
| RMS 1->2 | RMS Value Between Cursor 1 Location and Cursor 2 Location | Y1 |
| DEF AUX (DEFINE AUX) | Define Auxiliary Codes | Y2 |
| DSPL dB | Number of dB on Vertical Axis | Y3 |
| DISK | | Y4 |
| LIN | Linear Reference | Y5 |
| dB | Logarithmic Reference | Y6 |
| V/EU | Volts per Engineering Unit | Y7 |
| FREQ REF | Frequency Reference | Y8 |
| ORD REF (ORDER REF) | Order Reference | Y9 |

INPUT CHANNEL A

| | | |
|---|---|---|
| TEST | | C3 |
| AC | AC Coupled | C1 |
| DC | DC Coupled | C0 |
| INVERT (INV) | Invert Data | C5 |
| NORMAL (NOR) | Normal Data | C4 |
| ZERO | Zero Data | C6 |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

| | | |
|---|---|---|
| **MAX AMPLITUDE** | | |
| .1 | | A0 |
| .2 | | A1 |
| .5 | | A2 |
| 1 | | A3 |
| 2 | | A4 |
| 5 | | A5 |
| 10 | | A6 |
| 20 | | A7 |
| **INPUT CHANNEL B** | | |
| TEST | | D3 |
| AC | AC Coupled | D1 |
| DC | DC Coupled | D0 |
| INVERT (INV) | Invert Data | D5 |
| NORMAL (NOR) | Normal Data | D4 |
| ZERO | Zero Data | D6 |
| **MAX AMPLITUDE** | | |
| .1 | | B0 |
| .2 | | B1 |
| .5 | | B2 |
| 1 | | B3 |
| 2 | | B4 |
| 5 | | B5 |
| 10 | | B6 |
| 20 | | B7 |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

FREQUENCY RANGE

| | | |
|---|---|---|
| 1 Hz | | Q0 |
| 2 Hz | | Q1 |
| 5 Hz | | Q2 |
| 10 Hz | | Q3 |
| 20 Hz | | Q4 |
| 50 Hz | | Q5 |
| 100 Hz | | Q6 |
| 200 Hz | | Q7 |
| 500 Hz | | Q8 |
| 1 kHz | | Q9 |
| 2 kHz | | QA |
| 5 kHz | | QB |
| 10 kHz | | QC |
| 20 kHz | | QD |
| 50 kHz | | QE |
| 100 kHz | | QF |
| FREQ | Internal Sampling | N0 |
| ORDERS | External Sampling | N1 |

CAPTURE CONTROL

| | | |
|---|---|---|
| DATA TYPE | | |
| CONT | Continuous (Weighted) | T0 |
| TRAN (TRANS) | Transient (Unweighted) | T1 |
| TRIG SOURCE | | |
| CHA | | T2 |
| CHB | | T3 |
| HOLD/REL* | Complement Hold Release State | ! |
| ARM | Arm the Input Buffer | # |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

CAPTURE CONTROL (Con't.)

| | | |
|---|---|---|
| TRIG LEVEL | | |
| + 1/2 | Of Full Scale | L0 |
| + 1/4 | Of Full Scale | L1 |
| + 1/8 | Of Full Scale | L2 |
| + 1/16 | Of Full Scale | L3 |
| - 1/16 | Of Full Scale | L7 |
| - 1/8 | Of Full Scale | L6 |
| - 1/4 | Of Full Scale | L5 |
| - 1/2 | Of Full Scale | L4 |
| SYS RESET | System Reset | 'DC3' : (CNTRL/S) |

TEXT ENTRY

| | | |
|---|---|---|
| ABC | Entry A, B, or C | P0 |
| DEF | Entry D, E, or F | P1 |
| GHI | Entry G, H, or I | P2 |
| JKL | Entry J, K, or L | P3 |
| MNO | Entry M, N, or O | P4 |
| PQR | Entry P, Q, or R | P5 |
| STU | Entry S, T, or U | P6 |
| VWX | Entry V, W, or X | P7 |
| YZd | Entry Y, Z, or d | P8 |
| (<% | Entry (, <, or % | P9 |
| )>, | Entry ), >, or , | PA |
| '#: | Entry ', #, or : | PB |
| RUB | Delete character, blank rest of line, or enter NULL | PC |
| INS | Insert on or off | PD |
| | Second character select on or off | PE |
| | Third character select on or off | PF |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

FIGURE 19-6 (Con't.)

REMOTE CONTROL COMMANDS

SPECTRUM CALCULATION OPTION

| | | |
|---|---|---|
| CM | Complex Math Mode On or Off | [0 |
| VIEW C | View C On or Off | [1 |
| STO C | Store Scaled Data in C | [2 |
| IFFT | Perform IFFT on C Buffer Results in Time, or FFT on C Buffer Results in Frequency | [7 |

---

†660 Pushbutton abbreviations follow in ( ).
Ø Refers to the letter "O".
0 Refers to the number zero.
* Complements current state. Additional commands exist to set or reset state.

Issuing the codes associated with the joysticks from an interface causes one step to be taken in the appropriate direction. If more than one step is desired, the command must be reissued a number of times until the appropriate gain or cursor position is achieved. In the case of the cursor joystick, both stepsize commands for each direction are available to the interfaces.

C 2. Additional Remote Commands

In addition to the commands available on the 660B front panel, the interfaces can issue commands which provide important additional functions and useful features. These extra commands are listed separately in Figure 19-7 as additional remote control operations. The command codes are also shown on the diagram of the 660B front panel, Figure 19-5.

The definition and use of these commands are as follows:

a. Setting Complement Functions - The front panel contains pushbuttons which complement the states controlled by those pushbuttons. Since it may be difficult to ascertain the current state when remotely controlling the 660B, additional commmands are provided for setting the desired state regardless of the current state. These commands are grouped according to the section of the front panel on which they appear, i.e. DISPLAY, AMPLITUDE UNITS, SCALES, and CAPTURE CONTROL except for Option -8 commands which are grouped together. For example, in the AMPLITUDE UNITS section of the front panel, depressing the dB/LIN button, or issuing the code U0 from an interface, causes the current state to be complemented. If the code U4 is issued from an interface, the cursor reading will be in dB whether or not the current reading is in dB.

b. External I/O Blocksize Control - The blocksize is an important parameter when inputting or outputting a data buffer. The blocksize is the number of bytes the 660B considers a group during input or output. On output, the 660B uses the blocksize parameter to determine the number of fill characters to add if blockfill is desired (30 series of DEF AUX) and, if the RS232-C interface is being used, when to wait for the software handshake before continuing the output (60 series of DEF AUX). When data is input to the 660B, the predetermined blocksize must be strictly observed. See I/O Format Section for a detailed account of block size.

The blocksize can be set to any number of bytes from 1 to 2048, inclusive. The blocksize is set by issuing over an interface the command sequence: number SET BLOCKSIZE (SWA). For example, to set the blocksize to 1024 bytes, the following characters should be entered over the interface: 1024SWA, where 1024 is the blocksize desired, S is the code for the SET pushbutton, and WA is the code for blocksize control.

FIGURE 19-7

ADDITIONAL REMOTE COMMANDS

| SECTION and COMMAND | CODE |
|---|---|
| **DISPLAY Section** | |
| SET Recall | E4 |
| SET Compare | E5 |
| SET Equalize | E6 |
| CLEAR Recall, Compare, and Equalize | E7 |
| **AMPLITUDE UNITS Section** | |
| SET dB/LIN to dB | U4 |
| SET V/EU to V | U5 |
| SET ABS/REL to ABS | U6 |
| SET PER Hz 'ON' | U7 |
| RESET dB/LIN to LIN | U8 |
| RESET V/EU to EU | U9 |
| RESET ABS/REL to REL | UA |
| RESET PER Hz to 'OFF' | UB |
| **OUTPUT TYPE Section** | |
| SET PLOT to OFF | 04 |
| SET PLOT CAL to OFF | 05 |
| SET AUX to OFF | 06 |
| CRT ONLY | 07 |
| SET PLOT to ON | 08 |
| SET PLOT CAL to ON | 09 |
| SET AUX to ON | 0A |
| CRT ONLY | 0B |
| **SCALES Section** | |
| SET AMPL LOG/LIN to LOG | G2 |
| SET FREQ LOG/LIN to LOG | G3 |
| RESET AMPL LOG/LIN to LIN | G4 |
| RESET FREQ LOG/LIN to LIN | G5 |
| **CAPTURE CONTROL Section** | |
| Force Input Buffer to HOLD | $ |
| Release Input Buffer | " |

---

Ø Refers to the letter "O".
0 Refers to the number zero.

FIGURE 19-7 (Con't.)

ADDITIONAL REMOTE COMMANDS

| SECTION and COMMAND | CODE |
|---|---|
| SPECTRUM CALCULATION Option | |
| SET COMPLEX MATH MODE to ON | [3 |
| RESET COMPLEX MATH MODE to OFF | [4 |
| SET VIEW C to ON | [5 |
| RESET VIEW C to OFF | [6 |
| SET IFFT to ON, C CONTAINS TIME | [8 |
| RESET IFFT to OFF, C CONTAINS FREQ | [9 |
| ADDITIONAL COMMANDS Section | |
| External I/O Blocksize Control | WA |
| IEEE-488 SRQ Mask | WB |
| External I/O Initiate Commands | |
| Input to buffer n from RS232-C Interface | >n |
| Output from n over RS232-C Interface | =n |
| Input to n from IEEE-488 Interface | @n |
| Output from n over IEEE-488 Interface | ?n |
| Lock out Front Panel Operation[1] | 'DC1':(CNTRL/Q) |
| Enable Front Panel Operation[1] | 'DC4':(CNTRL/T) |
| Enter Entry Field APLHA Mode[1] | 'RS' :(CNTRL/^) |
| Exit Entry Field ALPHA Mode[1] | 'FS' :(CNTRL/\) |
| Invert Characters in Entry Field[1] | 'BEL':(CNTRL/G) |
| Output Status Byte over IEEE-488 Interface[1] | 'BS' :(CNTRL/H) |
| Output Status Byte over RS232-C Interface[1] | 'HT' :(CNTRL/I) |
| Used Internally | (CNTRL/A through CNTRL/F) |
| | CARRIAGE RETURN |
| | LINE FEED |

---

Ø Refers to the letter "O".
0 Refers to the number zero.
[1] The codes between quotes are the mnemonics for single ASCII characters generated by the keystrokes between the parentheses. 'CNTRL' means to hold the CNTRL key while depressing the character following the slash, for example, CNTRL/S means hold CNTRL while pressing S.

When the blocksize has been set, the entry field of the 660B will display: 1024 IOBS, indicating the I/O blocksize is now set to 1024 bytes. The current setting of the blocksize can be interrogated at any time by issuing over an interface the command: RECALL BLOCKSIZE (RWA). The current blocksize, followed by the letters IOBS, will be displayed in the entry field.

On power up and after a system reset, the blocksize is set to 72 bytes. The blocksize can be returned to the default state by issuing over an interface the command: CLEAR BLOCKSIZE (ZWA). The default blocksize is then displayed in the entry field.

The choice of blocksize is usually determined by the requirements of the device receiving data from, or sending data to, the 660B. When inputting data to the 660B, maximum transfer rates will be achieved if blocksizes of 1024 or less are used. WB, for an explanation of the SRQ mask, see the Appendix, "Setting the 488 Environment".

c. External I/O Initiate Commands - These commands allow the user to start a transfer of data to or from any of the 660B internal data buffers over either the RS232-C or the IEEE-488 interface. There are 16 data buffers numbered 0 through F, see Section 19-3, any of which can input or output. The current blocksize and DEFine AUX setable parameters are used for the data transfer. For example, to output the buffer containing the front panel settings (buffer 0) over the 488 interface, the desired blocksize and DEF AUX settings should be entered. When the receiver is ready to accept the data, the command: ?0 should be entered over an interface. Additional information about data transfers, I/O parameters, and available data buffers can be found in the section entitled, "Accessing Data," Section 19-3.

d. Front Panel Lock Out - When controlling the 660B with an interface, commands from the front panel will also be honored. Undesired results will be obtained, for example, if parameters for a data transfer are being set from an interface while, at the same time, another user changes the front panel settings. This is especially true if the 660B and the device remotely controlling the 660B are not in the same room. The conflicts between remote commands and front panel commands can be prevented by issuing the lock out front panel operation command (DC1 or control Q) from an interface. When this command is received by the system executive, all commands originating from the front panel are ignored. Hence, all the front panel pushbuttons and switches are locked out. In addition, to indicate that the front panel cannot be used, the REMOTE CONTROL LED is on.

One front panel button that can not be locked out is the "system reset" button. Pressing the SYS RST button, even when the REMOTE CONTROL light is on, will always return the 660B to the wake up state (and erase volatile memory).

After the lock out command has been issued, front panel operation can be reinstated by issuing the enable front panel operation (command DC4 or control T). When this command is received by the 660B, three events occur:

1. The system executive will be instructed not to ignore front panel commands, thus unlocking the front panel,

2. The remote control LED will be extinguished, and

3. The current setting of all front panel fixed switches will be interrogated since their positions could have been changed while the front panel was locked out.

e. Entry Field Alpha Mode - Character strings longer than 14 characters can be displayed in the 660B entry field using the alpha mode of the interfaces. Normally, any characters received from an interface are interpreted as command codes. If the entry field alpha mode command RS (control ^) is issued, however, all subsequent characters received from an interface will be scrolled into the entry field. As each character is received by the 660B, the 14 characters in the entry field shift one position to the left. The new character is placed in the right-most position, and the character which was formerly in the left-most position is lost.

To exit the alpha mode, two commands are available. The exit entry field alpha mode command FS (control \) causes all subsequent characters received over the interfaces to be interpreted as command codes. The BEL (control G) command has the same effect as the exit alpha mode command except that, in addition, the characters in the entry field are inverted.

The alpha mode is a special mode available to the interfaces and several limitations on the alpha mode should be noted:

1. If the front panel is not locked out and if any pushbutton is depressed or switch position is changed, the alpha mode is exited immediately and the command from the front panel is honored.

2. While in the alpha mode, any non-printing character will still be interpreted as a command, and no shifting of the entry field will result. The alpha mode will still be in effect unless the command generates an error message. If an error message overwrites the entry field, the character string may be restored by issuing one CLEAR command (the character Z). The alpha mode can now be re-entered and the character string completed. For example, if while in the alpha mode, a DC1 or (control Q) is received, the front panel will be locked out, but the character string can continue. If an EM (control Y) is received, the 660B will exit the alpha mode and display OPTION N/A in the entry field. Issuing the commands Z RS (control ^) will enable the user to continue entering the character string.

3. No backspace command exists for the alpha mode. If an error is made, the alpha mode must be exited, and the entry field cleared. The alpha mode can then be re-entered and characters scrolled into the entry field.

4. A dollar sign ($) is displayed as a lower case d and the underscore is displayed as $\sqrt{\ }$ (square root). No character exists which will cause a dollar sign or an underscore to be displayed.

f. Invert Characters in Entry Field - As mentioned in the previous section, a control G causes the 660B to exit the alpha mode and invert the characters in the entry field. In addition, a BEL (control G) causes the characters in the entry field to invert whether or not the 660B is currently in the alpha mode. Hence, any message placed in the entry field by the 660B, as well as user generated messages, can be inverted at any time. Once dark characters on a light background are displayed, light characters on a dark background can only be achieved by scrolling non-inverted characters into the entry field.

g. Output Status Byte - For the convenience of the user, the 660B groups some information which might be required into one 8-bit byte. This byte is called the 660B status byte. Each bit of this byte is assigned a meaning, as shown in Figure 19-8. Each bit has the same meaning as the corresponding LED on the front panel. Thus, the averager on bit corresponds to the LED on the START button and the HOLD, ARM, and PLOT bits correspond to the LEDs on the HOLD, ARM and PLOT pushbuttons, respectively. The overload status

660B STATUS BYTE

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| OVERLOAD | INTERNAL USE | PLOT ON | HOLD | ARM | INTERNAL USE | INTERNAL USE | AVERAGER ON |

OUTPUT FORMAT DETERMINED BY 30 SERIES DEFINE AUX

TERMINATORS SPECIFIED BY 50 SERIES DEFINE AUX ARE USED

FIGURE 19-8. 660B STATUS BYTE.

bit is turned on whenever an overload on either Channel A or Channel B occurs. Once this bit is on, it will not be turned off, even if the overload light goes out. The overload bit is cleared only upon starting an average. Hence, an average can be started by remote control and after the average is complete, the top bit of the status byte can be examined to determine if an overload occurred at any time during the averaging process.

Three formats are available for examining the status byte, binary, hexadecimal ASCII, and decimal ASCII. These are the same three formats which can be used to output or input data, see Section 19.3, "Accessing Data". The format used is determined by the current setting of the 30 series DEF AUX. Since blocksize is not used when outputting the status byte, blockfill specifications are irrelevant. If binary format is used (DEF AUX 34 or 35), the status byte is copied to the interface as is.

If hexadeciaml ASCII format is used (DEF AUX 32 or 33), two ASCII characters representing the hexadecimal equivalent of the status byte are sent over the interface. For example, if the bits in the status byte are 1010 0001 the 2 characters "A1" will be output. Decimal ASCII format (DEF AUX 30 or 31) will cause the status byte to be converted to decimal and the ASCII decimal digits will be output in a blank-filled field of 4 characters. Thus, if the status byte is 10100001* the 4 characters 'Ø168' (where Ø = blank) will output. If the format used is ASCII hexadecimal or decimal, the terminators specified by the 50 series of DEF AUX are added after the status byte. Additional information on number conversion and data formatting is given in "Accessing Data," Section 19-3.

The bits in the status byte do not change at exactly the same time as the corresponding event occurs, but rather the byte is updated when the LED is updated. Care should be taken when reading the status byte while the 660B is changing state. For example, if one average is requested, 1 SET AVG N (1SW0) and the averager is started (V8), it is possible for the averager to complete before the LED can be lit. Therefore, the status words averager on bit will not be set to 1. To circumvent this the user may issue a HOLD, then START AVG, then RELEASE. It is assured that the AVG ON bit will be 1, then go to 0 at the end of the average.

The overload status will only be updated if another event occurs, such as a new average, or a switch closure. If the overload bit must be updated, such as when remotely setting the gain controls, a SOH (control A) should be issued prior to each output of the status byte. The SOH (control A) causes the 660B status byte to be updated with the current status.

---

*(1010 0001 = 128 +32 + 1 = 168)

3. Acknowledging Commands

Each byte of a command sent to the 660B is acknowledged. The acknowledgment indicates:

1. The byte has been accepted and the next byte of the commmand string can be transmitted, and

2. The type of acknowledgment sent by the 660B indicates whether the command received was valid or invalid.

The acknowledgment process on the IEEE-488 interface is different from the process on the RS232-C interface. Over the RS232-C, an ACK byte (control F) is output on the RS232-C interface for each command byte entered. The ACK byte indicates that the 660B is ready for another command character to be entered and the character was a valid command. In the case of two character commands, an ACK is sent for each character of the command. An ACK byte does not indicate that the command has been performed, rather, the character was acceptable in the current context. When a character is received by the 660B, validity is determined. If the command is valid, the function requested by the command is initiated and an ACK byte is sent. If the character received is not a valid command, an error message is generated in the entry field and a NAK byte (control U) is output instead of an ACK. A NAK indicates that an invalid command was received and the 660B is ready to receive the next command. For each character sent, an ACK or a NAK byte is output.

Both the ACK and NAK characters are non-printing characters. If a terminal is being used to enter commmands remotely, it is unnecessary to view the ACK and NAK bytes since the 660B can generally respond to commands faster than the command can be typed. The entry field provides visual feedback that the command has been performed. If a programmable device is controlling the 660B, it is essential that no additional command be entered until an ACK or NAK corresponding to the previous command is issued. If this procedure is not followed, command characters will be lost, and undesired actions may be taken by the 660B due to command characters being taken out of context.

When using the IEEE-488 interface, normally a different acknowledgment process is used. The acknowledgment-indication that a character has been received and that the next character can be sent is provided separately in the hardware of the IEEE-488 interface. When the NDAC (Not Data Accepted) line is released (allowed to float high) by the 660B, a byte has been accepted from the bus. When the 660B

releases the NRFD (Not Ready for Data) line, the 660B is ready for the next byte to be sent. Hence, when a character is sent over the IEEE-488 interface, the 660B 'holds off' the NRFD handshake until it is ready to receive the next byte. The IEEE-488 handshake is then 'released' and the next character can be sent.

If an invalid command is received, the 660B still releases the handshake so that the next character can be sent. If service requests are being issued, the service request line (SRQ) of the IEEE-488 interface may be asserted to indicate to the IEEE-488 bus controller that an invalid command was received by the 660B. See Section 19-4. Thus on the IEEE-488 interface, the equivalent of an ACK is releasing the IEEE-488 handshake and the NAK equivalent is issuing a service request and then releasing the handshake. The service request is cleared when the controller performs a serial poll, thus getting the 660B serial poll status byte, which will indicate the NAK. If there is no controller on the bus or if SRQ's are not enabled, no service request is issued. See Section 19-4, Operation Without a 488 Bus Controller.

Each character sent over an interface generates an ACK or NAK equivalent. The exception to the ACK/NAK rule is the I/O input initiate command group and the control V handshake. In addition to issuing an ACK after each character of these commands is received, the 660B also issues an ACK or a NAK after the data transfer is complete to indicate whether or not the transfer was successful. If any error occurred during the transfer, a NAK will be issued. Data transfer errors are discussed in the "Accessing Data Section" which immediately follows.

## 19.3 Accessing Data

The external I/O initiate commands provide the means of accessing the 660B data buffers as discussed in "Controlling the 660B," Section 19.2. The contents of the data buffers, external data formats, and other data related interface considerations are discussed in this section. While the data buffers represent the majority of the information available to the user, other supplemental data is output using the AUX and the DISK pushbuttons. This supplemental data is discussed separately at the end of this section.

### A. Data Buffers Available

The data which can be output from or input to the 660B is summarized in Figure 19-9. The data is grouped into data buffers, each of which is assigned a number. This number is

FIGURE 19-9

DATA BUFFERS AVAILABLE

| BUFFER NUMBER | DATA AVAILABLE | INTERNAL FORMAT | LENGTH IN BYTES | COMMENTS |
|---|---|---|---|---|
| 0 | Front Panel Settings | 8-Bit Bytes | 111 | |
| 1 | Nonvolatile | 8-Bit Bytes | 1024 | Cursors 1 - 9 and Panels 1 - 9 |
| 2 | Scaled Octave Data Upper Trace | 3-Byte Floating Point Numbers | 90 | These buffers only contain data when in use or if Octave (Option -3) has been in use. |
| 3 | Scaled Octave Data Lower Trace | | | |
| 4 | First Averager Buffer | 3-Byte Floating Point Numbers Except 16-Bit Integers if in Probability Mode | 1539 | The data in the averager buffers depends on the current mode. The buffers contain magnitude of A, coherent component of the cross spectrum, and magnitude of B in the 1K FFT mode. |
| 5 | Second Averager Buffer | | | |
| 6 | Third Averager Buffer | | | |
| 7 | Fourth Averager Buffer | | | |
| 8 | First Display Memory Buffer | Same as Averager Buffers | 1539 | |
| 9 | Second Display Memory Buffer | | | |

NOTE: THE FRONT PANEL OF THE 660B IS LOCKED OUT DURING THE TRANSFER OF ANY BUFFER EXCEPT BUFFERS 2, 3, and F.

FIGURE 19-9 (Con't.)

DATA BUFFERS AVAILABLE

| BUFFER NUMBER | DATA AVAILABLE | INTERNAL FORMAT | LENGTH IN BYTES | COMMENTS |
|---|---|---|---|---|
| A | Display Memory Status | 8-Bit Bytes | 132 | Needed to correctly interpret display memory buffers. |
| B | Text Character Strings and Control | 8-Bit Bytes | 220 | Position and contents of text fields when displayed. |
| C<br>D | Real Part of Complex Math<br>Imaginary Part of Complex Math | 3-Byte Floating Point Numbers | 1539 | Can only contain if Option -8 is installed. |
| E | Averager Status | 8-Bit Bytes | 11 | Needed to correctly interpret averager buffers. |
| F | General Block | 8-Bit Bytes | User Variable | Enables user to access any portion of main memory. |

NOTE: THE FRONT PANEL OF THE 660B IS LOCKED OUT DURING THE TRANSFER OF ANY BUFFER EXCEPT BUFFERS 2, 3, and F.

used as the second character for the external I/O initiate commands, see Section 19.2, "Controlling the 660B." The contents of each data buffer is described in this section.

1. Front Panel Settings (Buffer 0)

All information related to the current set-up of the 660B is contained in buffer 0 (ZERO). Figure 19-10 lists the contents of each byte or group of bytes in this buffer. The numbers indicating the contents of a byte are shown as two hexadecimal digits.

If buffer 0 is output in decimal ASCII format, see "I/O Formats," Section 19.3, each byte is converted to a decimal number between 0 and 255 even if a byte is part of a group of bytes representing one number. For example, if the number of averages has been set to 500, bytes 27 and 28 (STAVGN) would be output as a 1 244 and may be reconstructed by ("1" x 256 + "244") = 500.

Note, although buffer 0 can be used to enter a 660B front panel set-up, no checks are made on the data. The 660B may be placed in an invalid state as a result of an improper input. Buffer 0 should only be used to re-enter a previously saved 660B set-up. To ensure validity, the set-up should be changed only by issuing remote commands or by front panel operations.

After an input of data to buffer 0, the 660B must be told to re-examine its state table to use the new data. This is accomplished by issuing a control A (ASCII SOH) via the controlling interface. This action need be taken only after a transfer to buffer 0.

2. Non-volatile Memory (Buffer 1)

This buffer is used to save front panel settings (Panels 0-9) and cursor locations (Cur Loc 0-9). The ten panels are stored sequentially, followed by the ten cursor locations. Each panel consists of the first 100 bytes of buffer 0, which are copied at the time of the panel save.

Each cursor consists of 2 bytes which form a 16-bit number representing the cell number of the saved cursor. The last 4 bytes of buffer 1 are used for diagnostic purposes.

FIGURE 19-10

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0000 | SSCURT | 1 | CURSOR TYPE<br>00 = OFF<br>01 = SINGLE<br>02 = HARMONIC |
| 0001 | SSFRQR | 1 | FREQUENCY READS<br>00 = Hz<br>01 = CPM<br>02 = ORDERS |
| 0002 | SSAADT | 1 | CHANNEL A AC/DC/TEST<br>BIT 1=0 = NORMAL INPUT<br>BIT 1=1 = TEST INPUT<br>BIT 0=0 = DC COUPLED<br>BIT 0=1 = AC COUPLED |
| 0003 | SSAINZ | 1 | CHANNEL A NORMAL/INVERT/ZERO<br>00 = NORMAL<br>01 = INVERT<br>02 = ZERO |
| 0004 | SSAAMP | 1 | CHANNEL A INPUT AMPLITUDE<br>00 = 0.1<br>01 = 0.2<br>02 = 0.5<br>03 = 1.0<br>04 = 2.0<br>05 = 5.0<br>06 = 10.0<br>07 = 20.0 |
| 0005 | SSBADT | 1 | CHANNEL B AC/DC/TEST<br>SAME CODING AS CHANNEL A |
| 0006 | SSBINZ | 1 | CHANNEL B NORMAL/INVERT/ZERO<br>SAME CODING AS CHANNEL A |
| 0007 | SSBAMP | 1 | CHANNEL B INPUT AMPLITUDE<br>SAME CODING AS CHANNEL A |
| 0008 | SSFROR | 1 | FREQUENCY/ORDERS<br>00 = FREQUENCY<br>01 = ORDERS |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0009 | SSFREQ | 1 | FREQUENCY RANGE<br>00 = 1 Hz<br>01 = 2 Hz<br>02 = 5 Hz<br>03 = 10 Hz<br>04 = 20 Hz<br>05 = 50 Hz<br>06 = 100 Hz<br>07 = 200 Hz<br>08 = 500 Hz<br>09 = 1 kHz<br>0A = 2 kHz<br>0B = 5 kHz<br>0C = 10 kHz<br>0D = 20 kHz<br>0E = 50 kHz<br>0F = 100 kHz |
| 0010 | SSTRGS | 1 | TRIGGER SOURCE<br>00 = CHANNEL A<br>01 = CHANNEL B |
| 0011 | SSTRGL | 1 | TRIGGER LEVEL<br>00 = +1/2<br>01 = +1/4<br>02 = +1/8<br>03 = +1/16<br>04 = -1/2<br>05 = -1/4<br>06 = -1/8<br>07 = -1/16 |
| 0012 | STMODE | 1 | PROCESSING MODE<br>00 = MODE 0 = SIG ENH<br>01 = MODE 1 = 2K FFT<br>02 = MODE 2 = 1K FFT<br>03 = MODE 3 = CORR<br>04 = MODE 4 = PROB<br>05 = MODE 5 = TEXT MODE*<br>06 = MODE 6 = SPARE<br>07 = MODE 7 = SPARE<br>08 THROUGH FF = INVALID |

*TEXT MODE is a mode modifier; it will not be indicated as a separate mode, however, no mode 5 will exist, since logically text occupies this position.

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0013 | STFUNC | 1 | FUNCTION SELECTED<br>00 = FUNCTION 0 = INPUT TIME<br>01 = FUNCTION 1 = AVG TIME<br>02 = FUNCTION 2 = CROSS SPEC<br>03 = FUNCTION 3 = TF (TRANSFER FUNCTION)<br>04 = FUNCTION 4 = INST SPEC<br>05 = FUNCTION 5 = RMS SPEC<br>06 = FUNCTION 6 = POWER SPEC<br>07 = FUNCTION 7 = COP<br>08 = FUNCTION 8 = SPARE<br>09 = FUNCTION 9 = IMPL RESP<br>0A = FUNCTION 10 = TM (TRANSMIS-SIBILITY)<br>0B = FUNCTION 11 = COH<br>0C = FUNCTION 12 = AUTO CORR<br>0D = FUNCTION 13 = CROSS CORR<br>0E = FUNCTION 14 = SPARE<br>0F = FUNCTION 15 = SPARE<br>10 = FUNCTION 16 = PROB DEN<br>11 = FUNCTION 17 = CUM DIST<br>12 = FUNCTION 18 = VIEW C<br>13 = FUNCTION 19 = VIEW C, IFFT<br>14 THROUGH FF = INVALID |
| 0014 | STCHNN | 1 | DISPLAY CHANNEL<br>00 = INVALID<br>01 = CHANNEL A<br>02 = CHANNEL B<br>03 = CHANNEL A & B<br>04 = CROSS PROPERTIES |
| 0015 | STFRMT | 1 | DISPLAY FORMAT<br>00 = REAL<br>01 = IMAG<br>02 = REAL/IMAG<br>03 = NYQ<br>04 = MAG<br>05 = PHASE<br>06 = PHASE/MAG<br>07 = SPARE |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0016 | STAVGM | 1 | AVERAGER MODE<br>X0 = SUM<br>X1 = DIFF<br>X2 = EXPO<br>X3 = PEAK<br>04 = SWEEP*<br>X5 = SPARE<br>X6 = SPARE<br>0X = CONTINUOUS AVERAGING<br>8X = TRANSIENT AVERAGING*<br><br>*84 = NOT VALID (TRANSIENT SWEEP) |
| 0017 | STDMST | 1 | DISPLAY MEMORY STATUS<br>00 = NOT RECALL, OR COMP, OR EQL TF/TM<br>01 = RECALL (Bit 0 = 1)<br>02 = COMP (Bit 1 = 1)<br>03 = INVALID<br>04 = EQL TF/TM (Bit 2 = 1)<br>05 THROUGH FF = INVALID |
| 0018 | STOUTT | 1 | OUTPUT TYPE<br>BIT 0=0 PLOT NOT IN PROGRESS<br>BIT 0=1 PLOT IN PROGRESS<br>BIT 1=0 PLOT SETUP NOT IN PROGRESS<br>BIT 1=1 PLOT SETUP IN PROGRESS<br>BIT 2=0 AUX LED OFF<br>BIT 2=1 AUX LED ON<br>BIT 4, BIT 3 =<br>0,0 POSITION 1 OF PLOT SETUP<br>0,1 POSITION 2 OF PLOT SETUP<br>1,0 POSITION 3 OF PLOT SETUP<br>1,1 POSITION 4 OF PLOT SETUP |
| 0019 | STSCLS | 1 | DISPLAY SCALES<br>BIT 0=0 = LIN VERT<br>BIT 0=1 = LOG VERT<br>BIT 1=0 = LIN HORZ<br>BIT 1=1 = LOG HORZ<br>BITS 7 to 2 = NOT USED |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0020 | STCRDS | 1 | CURSOR READS FLAGS<br>BIT 0=0 = LIN UNITS<br>BIT 0=1 = LOG (DB) UNITS<br>BIT 1=0 = ENGINEERING UNITS<br>BIT 1=1 = VOLTS<br>BIT 2=0 = RELATIVE<br>BIT 2=1 = ABSOLUTE<br>BIT 3=0 = NORMALIZED TO BETA<br>BIT 3=1 = NORMALIZED PER HZ |
| 0021 | STDTYP | 1 | DATA TYPE CONTROL<br>00 = CONTINUOUS<br>01 = TRANSIENT<br>02 = ZERO CORRELATION<br>03 THROUGH FF = INVALID |
| 0022 | STFRRD | 1 | FREQUENCY READS<br>BIT 0=0 = ABSOLUTE FREQUENCY<br>BIT 0=1 = RELATIVE FREQUENCY<br>BIT (1, 7) =0 = TRANSLATOR OFF<br>BIT (1, 7) =1 = TRANSLATOR ON<br>BITS 2-4 = NOT USED<br>BIT 5=0 = NO COH BLANKING DURING AVERAGING<br>BIT 5=1 = COH BLANKING DURING AVERAGING<br>BIT 6=0 = NO COH BLANKING<br>BIT 6=1 = COH BLANKING |
| 0023 | STDSPD | 1 | DISPLAY DB RANGE<br>00 = INVALID<br>01 THROUGH 08 = NUMBER OF DB/20<br>09 THROUGH FF = INVALID |
| 0024 | STPLTR | 1 | PLOT RATE<br>00 THROUGH 05 = SLOW THROUGH FAST<br>06 THROUGH FF = INVALID |
| 0025 | STINDA | 1 | INTEGRATE/DIFFERENTIATE FLAG CHANNEL A<br>FE = DOUBLE DIFF (-2)<br>FF = SINGLE DIFF (-1)<br>00 = NONE (0)<br>01 = SINGLE INT (+1)<br>02 = DOUBLE INT (+2)<br>03 THROUGH FD = INVALID |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0026 | STINDB | 1 | INT/DIFF FLAG CHANNEL B<br>SAME AS CHANNEL A |
| 0027 | STAVGN | 2 | AVERAGER N SETTING<br>1 THROUGH 9999 |
| 0029 | STAVGX | 2 | AVERAGER N SETTING FOR EXP MODE<br>1 THROUGH 4096 IN POWERS OF 2 |
| 0031 | STEXPN | 1 | LOG BASE 2 OF STAVGX<br>00 THROUGH 0C = VALID |
| 0032 | STDLTA | 2 | DELAY FROM TRIGGER TO END OF A WINDOW<br>IN SAMPLES |
| 0034 | STDLAB | 2 | DELAY FROM A TO B WINDOWS<br>IN SAMPLES |
| 0036 | | 2 | NOT USED |
| 0038 | STDCRN | 1 | DECIMATION RATIO NUMBER FOR DRT |
| 0039 | STRXR | 5 | RATIO OF DRT CENTER FREQUENCY TO BASEBAND FREQUENCY RANGE, DIVIDED BY 1.024 IN ALL RANGES EXCEPT 100 KHZ. 40 BIT INTEGER |
| 0044 | STFRRF | 5 | FREQUENCY REFERENCE<br>40 BIT INTEGER |
| 0049 | STORDR | 5 | ORDER REFERENCE IN HZ<br>40 BIT INTEGER |
| 0054 | STCOHB | 3 | COHERENCE BLANKING LEVEL<br>FLOATING POINT |
| 0057 | STREFA | 3 | EU PER VOLTS REFERENCE FOR CHANNEL A<br>FLOATING POINT |
| 0060 | STREFB | 3 | EU PER VOLTS REFERENCE FOR CHANNEL B<br>FLOATING POINT |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0063 | STREFR | 3 | REFERENCE LEVEL FOR RELATIVE READINGS<br>FLOATING POINT |
| 0066 | STULGM | 3 | TOP (MAX) FOR UPPER DISPLAY IN LOG<br>FLOATING POINT |
| 0069 | STULNM | 3 | TOP (MAX) FOR UPPER DISPLAY IN LIN<br>FLOATING POINT |
| 0072 | STLLGM | 3 | TOP (MAX) FOR LOWER DISPLAY IN LOG<br>FLOATING POINT |
| 0075 | STLLNM | 3 | TOP (MAX) FOR LOWER DISPLAY IN LIN<br>FLOATING POINT |
| 0079 | STBLKS | 2 | MAXIMUM I/O BLOCKSIZE<br>2048 MAX |
| 0080 | STOUTA | 1 | AUX OUTPUT TYPE (DEFINE AUX 0-9)<br>00 = "AT CURSOR" FOR ANALOG PLOTTER<br>01 = TO DIGITAL PLOTTER OVER RS232<br>02 = TO DIGITAL PLOTTER OVER 488<br>03 = CURSOR FIELDS OUTPUT OVER RS232<br>04 = CURSOR FIELDS OUTPUT OVER 488<br>05 THROUGH 09 = SPARE<br>0A THROUGH FF = INVALID |
| 0081 | STREDN | 1 | REDUNDANCY FLAG (DEFINE AUX 10-13)<br>BIT 0=0 = 50 PERCENT REDUNDANCY<br>BIT 0=1 = 0 PERCENT REDUNDANCY<br>BIT 1=0 = NORMAL TRIGGERING<br>BIT 1=1 = BLOCK SYNC TRIGGERING |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0082 | STANOT | 1 | ANNOTATION/GRATICULE CONTROL (DEFINE AUX 20-27)<br>BIT 0=0 = GRATICULE ON<br>BIT 0=1 = GRATICULE OFF<br>BIT 1=0 = ANNOTATION ON<br>BIT 1=1 = ANNOTATION OFF<br>BIT 2=0 = DATA ON<br>BIT 2=1 = DATA OFF<br>BITS 3-7 = NOT USED |
| 0083 | STOUTF | 1 | DATA I/O FORMAT (DEFINE AUX 30-37)<br>00 = ASCII DECIMAL, NO BLOCK FILL<br>01 = ASCII DECIMAL, WITH BLOCK FILL<br>02 = ASCII HEX, NO BLOCK FILL<br>03 = ASCII HEX, WITH BLOCK FILL<br>04 = BINARY, NO BLOCK FILL<br>05 = BINARY, WITH BLOCK FILL<br>06 = S0/S1 FORMAT, OUTPUT ONLY<br>07 = S0/S1/S9 FORMAT, OUTPUT ONLY<br>08, 09 = SPARE<br>0A THROUGH FF = INVALID |
| 0084 | STNOISE | 1 | SINE WAVE AT CURSOR CONTROL (DEFINE AUX 40-44)<br>00 = OFF<br>01 = SINE WAVE<br>02 = PSEUDO RANDOM NOISE<br>03 = PERIODIC NOISE<br>04 THROUGH FF = INVALID |
| 0085 | STOTRM | 1 | ASCII OUTPUT TERMINATOR CHARACTERS (DEFINE AUX 50-55)<br>FIRST BLOCK / LAST BLOCK<br>00 = NONE / NONE<br>01 = NONE / ETX<br>02 = CR / CR<br>03 = CR / CR, ETX<br>04 = CR, LF / CR, LF<br>05 = CR, LF / CR, LF, ETX |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0086 | STOHSH | 1 | OUTPUT HANDSHAKE ON/OFF FOR RS232 INTERFACE (DEFINE AUX 60-61)<br>00 = OFF<br>01 = ON |
| 0087 | STDIAG | 1 | DIAGNOSTIC FLAG BITS (DEFINE AUX 70-79)<br>BIT 0=1 = FFT BYPASS<br>BIT 1=1 = ECHO OFF<br>BIT 2=1 = NO FFT FUNCTIONS PERFORMED |
| 0088 | STPAGE | 1 | ZETA 136A PLOTTER AUTO-PAGING FUNCTION (DEFINE AUX 80-89)<br>0 = NO PAGES EJECTED<br>1 = ONE PAGE EJECTED<br>2 = TWO PAGES EJECTED<br>3 = THREE PAGES EJECTED<br>\|<br>9 = NINE PAGES EJECTED |
| 0089 | STTEXT | 1 | TEXT FIELD VIEWING SELECTION (DEFINE AUX 90-95)<br>0 = NO TEXT FIELDS DISPLAYED<br>1 = FIELD #1 DISPLAYED<br>2 = FIELD #2 DISPLAYED<br>3 = FIELD #3 DISPLAYED<br>4 = FIELD #4 DISPLAYED<br>5 = FIELDS #1-4 DISPLAYED |
| 0090 | STNAMP | 1 | AMPLITUDE OF OUTPUT FROM SINE WAVE AT CURSOR BOARD (DEFINE AUX 100-199) |
| 0091 | STOCTSTAT | 1 | OCTAVE OPTION CONTROL (DEFINE AUX 200-207)<br>BIT 0=1 = 2 PASS SYSTEM<br>BIT 0=0 = 1 PASS SYSTEM<br>BIT 1=1 = 1/1 OCTAVE<br>BIT 1=0 = 1/3 OCTAVE<br>BIT 2=1 = A WEIGHTING ON<br>BIT 2=0 = A WEIGHTING OFF |

FIGURE 19-10 (Con't.)

CONTENTS OF DATA BUFFER 0

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0092 | STCMDB | | FORMAT VIEW C<br>(DEFINE AUX 210-211)<br>0 = FORMAT VIEW C AS POWER (10 LOG dB)<br>1 = FORMAT VIEW C AS VOLTAGE (20 LOG dB) |
| 0093 | | 1 | SPARE |
| 0094 | STINDC | 1 | INTEGRATE/DIFFERENTIATE FLAG FOR VIEW C<br>$FE = DOUBLE DIFFERENTIATION<br>$FF = SINGLE DIFFERENTIATION<br>$00 = NONE<br>$01 = SINGLE INTEGRATION<br>$02 = DOUBLE INTEGRATION<br>$03 THROUGH $FD INVALID |
| 0095 | STREFC | 3 | VOLTS PER EU REFERENCE FOR VIEW C (FLOATING POINT) |
| 0098 | STCVIEW | 1 | 0 = NOT VIEWING COMPLEX MATH BUFFER C, ELSE<br>TOP FIVE BITS = 4-0 OF STFUNC<br>LOW THREE BITS = BITS 2-0 OF STCHNN<br>SAVES FUNCTION AND CHANNEL TO BE RESTORED ON EXIT FROM VIEW C |
| 0099 | OCTSTATUS | 1 | CURRENT STATE OF OPTION -3<br>BIT 0=1 = OPTION -3 TURN ON IN PROGRESS<br>BIT 1=1 = OPTION -3 ON<br>BIT 2=1 = OPTION -3 TURN OFF IN PROGRESS<br>BIT 3=1 = AVERAGER TO BE STOPPED AFTER PASS 2<br>BIT 4=1 = 2 PASS SYSTEM<br>BIT 5=1 = 1/1 OCTAVE<br>BIT 6=1 = A WEIGHTING ON<br>BIT 7=1 = FORCE CURSOR TO CENTER |
| 0100 | | 12 | SPARE |

3. Octave Buffers (Buffers 2 and 3)

Each buffer contains 30 three-byte floating point numbers. In 1/3 Octave, a one pass system places data in points 16-30 and a two pass system fills all 30 points. In 1/1 Octave, a one pass system places data in points 6-10 and a two pass system fills points 1-10. Buffer 2 is the upper or single trace, buffer 3 is the lower trace. The data in these buffers is already scaled and should match the displayed "at cursor" values.

These buffers will be empty unless Option -3 is or has been on.

4. Averager Buffers (Buffers 4, 5, 6, and 7) and Averager Status Buffer (Buffer E)

The averager buffers contain the data needed to generate any averaged function. The data stored in these buffers is dependent upon the mode selected as shown in Figure 19-11.

The data stored in the averager buffers is unscaled data which may be used to calculate any of the available functions for that mode. The formulas for obtaining these functions, as well as the formulas for applying the scale factor contained in buffer 0, can be found in "Calculating and Scaling 660B Data," Section 19.3, Paragraph 7.

The averager status buffer (Figure 19-12) contains information necessary to correctly interpret the averager buffers. This buffer, as well as buffer 0, should be saved whenever the averager buffers are saved.

5. Display Memory Buffers (Buffers 8 and 9) and Display Memory Status Buffer (Buffer A)

The display memory buffers are the areas where data is stored when the display memory STORE button is depressed. The data saved varies with mode, function, and format as indicated in Figure 19-13.

The display memory status buffer contains all the information necessary to correctly interpret the display memory buffers. This status buffer contains a copy of the averager status and front panel settings (buffers E and 0) at the time the display memory store pushbutton was depressed, see Figure 19-14. Only buffer A need be saved with buffers 8 and 9.

6. Text Buffer (Buffer B)

The text buffer is used to save or restore the four text fields described in the Section 18. The buffer contains the four-45 character fields and 32 bytes of position control status. The buffer does not control which text is on the display. This is specified by the 90 DEF AUX series. Figure 19-14A details the contents of the text buffer.

7. Complex Math Buffer (Buffers C and D)

I/O buffers C and D are the real and imaginary parts, respectively, of the Complex Math buffer C. Data in C is always scaled. If buffers C and D are output while C contains time domain data, I/O buffer C contains points 0-512 and D contains points 513-1026 (the last points are invalid).

I/O buffers C and D will only contain data if Option -8 is or has been turned on.

8. General Block (Buffer F)

Buffer F does not correspond to any internal data buffer in the 660B, but rather enables the user to access any portion of the 660B volatile memory. When using buffer F, the blocksize is interpreted not as a blocksize, but as the number of internal bytes to be transferred. This byte count may differ from the number of characters that are output or input, depending on the format selected. For example, if the blocksize has been set to 20 and hexadecimal format is selected, 40 characters will be output since for each byte, two hexadecimal digits are output.

The starting location for the I/O is determined by an address placed in the entry field. This address is assumed to be in hexadecimal unless the digits are followed by a decimal point, in which case the address is assumed to be decimal. For example, to output the 25 bytes starting at location $40A0_{16}$ over an interface, the following commands would begin the output:

| | |
|---|---|
| 25SWA | Set Blocksize to 25 |
| Control A | Enter Entry Field Alpha Mode |
| 40A0 | Scroll Address into Entry Field |
| Control \ | Enter Entry Field Alpha Mode |
| ?F | Output Buffer F over the IEEE-488 Interface |

Since the number of bytes transferred is controlled by the blocksize, this number must be between 1 and 2048, inclusive.

FIGURE 19-11

CONTENTS OF AVERAGER BUFFERS

1. Signal Enhancement Mode

| Buffer Number(s) | Length (Bytes) | Contents |
|---|---|---|
| 4, 5 | 3072 | Averaged Channel A time data in floating point (1024 Data Points). |
| 6, 7 | 3072 | Averaged Channel B time data in floating point (1024 Data Points). |

2. 2K FFT Mode

| Buffer Number(s) | Length (Bytes) | Contents |
|---|---|---|
| 4, 5 | 3075 | Averaged Channel A Power Spectrum (1025 Data Points). First Point is Cell 0 or DC. |

3. 1K FFT Mode and Corr Mode

| Buffer Number(s) | Length (Bytes) | Contents |
|---|---|---|
| 4 | 1539 | Averaged Channel A Power Spectrum (513 Data Points). First Point is Cell 0 or DC. |
| 5 | 1539 | Averaged Cross Spectrum Real (513 Data Points). |
| 6 | 1539 | Averaged Cross Spectrum Imaginary (513 Data Points). First Point (DC) and Last Point (Cell 513) are Zero. |
| 7 | 1539 | Averaged Channel B Power Spectrum (513 Data Points). |

FIGURE 19-11 (Con't.)

CONTENTS OF AVERAGER BUFFERS

4. Prob Mode

| Buffer Number(s) | Length (Bytes) | Contents |
|---|---|---|
| 4 | 1024 | Channel A Probability Density. 256 Data Points of 4 bytes each. First Data Point (4 byte) is total count of points (used for normalization). Remaining 255 Data Points are the number of occurences in each 'bin'. Data Points are arranged as follows: |

| NEXT TO LEAST SIGNIFI- CANT BYTE | LEAST SIGNIFI- CANT BYTE | MOST SIGNIFI- CANT BYTE | NEXT TO MOST SIGNIFI- CANT BYTE |
|---|---|---|---|
| LOW ADDR | | | HI ADDR |

| Buffer Number(s) | Length (Bytes) | Contents |
|---|---|---|
| 5 | 1024 | Channel B Probability Density. Same format as Prob Mode 4, above. |

NOTE: WHERE TWO BUFFER NUMBERS ARE INDICATED, THE DATA IS STORED SEQUENTIALLY, STARTING WITH THE FIRST BUFFER INDICATED.

IF THE DATA DOES NOT FILL A BUFFER, THE EXTRA BYTES ARE MEANINGLESS.

FIGURE 19-12

AVERAGER STATUS BUFFER

| OFFSET FROM FIRST BYTE | NAME | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|---|
| 0000 | ASONOF | 1 | AVERAGER ON/OFF<br>00 = OFF<br>01 = ON |
| 0001 | ASDSPN | 2 | VALUE OF N FOR NORMALIZATION OF DISPLAY |
| 0003 | ASCNT | 2 | COUNT OF NUMBER OF AVG FOR SUM SWEEP AND TRANS MODES SET TO 1 FOR EXP AND PEAK MODES (FOR NORMALIZATION) |
| 0005 | ASDCNT | 2 | COUNT OF NUMBER OF AVG FOR DIFF MODE |
| 0007 | ASDSPC | 2 | VALUE OF COUNT FOR DISPLAY IN ALL MODES (USED WHEN THE SEQUENCE RECALL AVG N IS ENTERED) |
| 0009 | ASLIMC | 2 | LIMIT VALUE OF COUNT (ZERO FOR CONTINUOUS MODES) |

FIGURE 19-13

CONTENTS OF DISPLAY MEMORY BUFFERS (BUFFERS 8 AND 9)

| MODE | FUNCTION | CHANNEL | FORMAT | CONTENTS |
|---|---|---|---|---|
| Any but 2K FFT | Input Time | A or B | | Contents of A or B Input buffer converted to floating point. 1024 data points, 3072 bytes. |
| Sig Enh | Avg Time | A or B | | Copy of contents of Avg buffer. 1024 data points, 3072 bytes. |
| Sig Enh or 1K FFT or Corr | Inst Spec | A or B | | Channel A or B Inst Spectrum. Real/Imag in floating point. 511 data points (1533 bytes) each). Real in buffer 8. Imaginary in buffer 9. NOTE: DC point is not stored. First point is cell 1. |
| Sig Enh or 1K FFT or Corr | Inst Spec | A and B | Real or Imag or Mag | Channel A data in buffer 8; Channel B data in buffer 9 in requested format. 511 data points (1533 bytes) each. NOTE: DC point is not stored. First point is cell 1. |
| Sig Enh or 1K FFT or Corr | Inst Spec | A and B | Phase | Channel A data in buffer 8. Channel B data in buffer 9. There are 511 data points in each buffer (1533 Bytes). No DC point is stored. Data is stored as 3 bytes. The first byte contains no information. The remaining two bytes form a 16-bit number representing the phase as a fraction of one rotation. Binary point is after the sign bit. |

FIGURE 19-13 (Con't.)

CONTENTS OF DISPLAY MEMORY BUFFERS (BUFFERS 8 AND 9)

| MODE | FUNCTION | CHANNEL | FORMAT | CONTENTS |
|---|---|---|---|---|
| 2K FFT | Inst Spec | A | Real or Imag or Mag | Data in requested format in floating point. 1023 data points, 3069 bytes. NOTE: DC point is not stored. First point is cell 1. |
| 2K FFT | Inst Spec | A | Phase | Phase data stored. 1023 data points, 3069 bytes. No DC point stored. First data point is cell 1. Data format same as phase on other modes, see previous. |
| 2K FFT | RMS Spec or Power Spec | A | | Copy of averager buffers 4 and 5. (Power Spectrum) 1025 data points, 1539 bytes each. |
| 1K FFT or Corr | RMS Spec or Power Spec | | | Copy of averager buffers 4 and 7. That is, Power Spectrum A and Power Spectrum B. 1513 data points, 1539 bytes each. |
| 1K FFT or Corr | COP | | | Coherent Output Power in floating point. 513 data points, 1539 bytes. Buffer 9 not used. |
| 1K FFT | COH | | | Coherence data in floating point. 513 data points, 1539 bytes. Buffer 9 not used. |
| 1K FFT or Corr | Cross Spec | | | Cross Spectrum Real and Imaginary. Real stored in buffer 8. Imaginary stored in buffer 9. 513 floating point data points each, 1539 bytes each. |

FIGURE 19-13 (Con't.)

CONTENTS OF DISPLAY MEMORY BUFFERS (BUFFERS 8 AND 9)

| MODE | FUNCTION | CHANNEL | FORMAT | CONTENTS |
|---|---|---|---|---|
| 1K FFT or Corr | TM | | | Transmissibility Function. 513 floating point data points, 1539 bytes. Buffer 9 not used. |
| 1K FFT or Corr | Auto Corr | | | Sa[illegible]s RMS Spec or Power Spec. |
| 1K FFT or Corr | Cross Corr | | | Cross Correlation Function in floating point. 1024 data points, 3072 bytes. |
| 1K FFT | Impulse Response | | | Impulse Response Function in floating point. 1024 data points, 3072 bytes. |
| 1K FFT | TF | | | Transfer Function Real and Imaginary. Real stored in buffer 8 and Imaginary stored in buffer 9. 513 floating point data points each, 1539 bytes each. |
| PROB | Prob Den or Cum Dist | | | Copy of Averager buffers 4 and 5. 1024 bytes each. |

FIGURE 19-14

CONTENTS OF DISPLAY MEMORY

STATUS BUFFER (BUFFER A)

| OFFSET FROM FIRST BYTE | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|
| 0 | 1 | DMTYPE<br><br>$FF = NO STORED DATA,<br>OTHERWISE<br>BIT 2-0 = 000 REAL<br>001 IMAG<br>010 REAL & IMAG<br>100 MAGNITUDE<br>101 PHASE<br>BIT 6 = 0 NARROWBAND (NORMAL DATA)<br>BIT 6 = 1 OCTAVE DATA<br>BIT 7 = 0 SINGLE CHANNEL<br>BIT 7 = 1 DUAL CHANNEL |
| 1 | 2 | DM = CURSOR LOCATION AT TIME OF DISPLAY MEMORY STORAGE |
| 3 | 11 | COPY OF AVERAGER STATUS BUFFER (Buffer E) |
| 14 | 1 | RS232 BAUD RATE<br><br>00 = 110 BAUD 2 STOPBITS<br>01 = 150 BAUD 1 STOPBIT<br>02 = 300 BAUD 1 STOPBIT<br>03 = 600 BAUD 1 STOPBIT<br>04 = 1200 BAUD 1 STOPBIT<br>05 = 2400 BAUD 1 STOPBIT<br>06 = 4800 BAUD 1 STOPBIT<br>07 = 9600 BAUD 1 STOPBIT |
| 15 | 1 | SPARE |
| 16 | 1 | RS232 PARITY<br><br>00 = EVEN<br>01 = ODD<br>02 = NONE<br>03 = NONE |

FIGURE 19-14 (CON'T.)

CONTENTS OF DISPLAY MEMORY

STATUS BUFFER (BUFFER A)

| OFFSET FROM FIRST BYTE | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|
| 17 | 1 | 488 ADDRESS |
| 18 | 1 | 00 THROUGH IE = VALID<br>IF THROUGH FF = INVALID<br>SPARE |
| 19 | 1 | 488 CONTROLLER PRESENT<br>00 = NO CONTROLLER<br>01 = CONTROLLER |
| 20 | 111 | COPY OF FRONT PANEL SETTINGS (Buffer 0) |

FIGURE 19-14A

CONTENTS OF TEXT BUFFER (BUFFER B)

| OFFSET FROM FIRST BYTE | LENGTH (BYTES) | DESCRIPTION |
|---|---|---|
| 0 | 45 | CHAR TEXT STRING #1, |
| | *00 | (END OF STRING NULL) |
| 46 | 45 | CHAR TEXT STRING #2, |
| | *00 | (END OF STRING NULL) |
| 92 | 45 | CHAR TEXT STRING #3, |
| | *00 | (END OF STRING NULL) |
| 138 | 45 | CHAR TEXT STRING #4, |
| | *00 | (END OF STRING NULL) |
| | \| | FIELD #1 POSITION CONTROL |
| | \|*0200 | NOTE 1 |
| 186 | \| XXXX | 16-BIT UNSIGNED X POSITION OF |
| | \| | 1ST CHARACTER |
| 188 | \| YYYY | 16-BIT UNSIGNED Y POSITION OF |
| | \| | 1ST CHARACTER |
| | \| *07 | NOTE 1 |
| | \|*---- | NOTE 1 |
| 195 | \| X | SAME FOR FIELD #2 |
| 197 | \| Y | |
| 204 | \| X | SAME FOR FIELD #3 |
| 206 | \| Y | |
| 213 | \| X | SAME FOR FIELD #4 |
| 215 | \| Y | |

* For proper operation, user should not alter these values.

NOTE 1: Internal Control Bytes.

NOTE 2: X and Y reference upper left of 1st character. Character size is 400 x 400 hexidecimal. The 0,0 coordinates are the extreme lower left of the CRT screen. Power up coordinates are X = 0 and Y = A800.

9. Calculating and Scaling Data

This section describes how data and scaling factors sent over the interface can be combined to determine equivalent input (BNC terminal) scaled values. However, before presenting the equations, an overview of the data organization will clarify how to use the equations.

a. Data Overview - Data is supplied from six buffers, buffers 4, 5, 6, and 7 called the averager buffers and buffers 8 and 9 called the display memory buffers. The associated scaling information for these two groups is located in buffers E and 0 for the averaged data and buffer A for the display memory buffers.

Three general types of data are used within the 660B Spectrum Analyzer - instantaneous, averaged and derived (calculated) data.

1. Instantaneous Data - These data include instantaneous time and spectrum data. These data are not normally found in the above six buffers and cannot be accessed over the interface unless transferred to the display memory buffer. Therefore, buffers 8 & 9 are used to obtain instantaneous spectrum data. The data format consists of 24-bit floating point numbers. The instantaneous spectrum data consist of the real and imaginary components of the spectrum.

2. Averaged Data - Data found in the averager buffers is either time, probability density, or four spectrum quantities: Power Spectrum A, Power Spectrum B, the Colinear (CO) component of the Cross Spectrum, and the Quadrature (QUAD) component of the Cross Spectrum.

3. Derived (Calculated) Data - Most of the functions displayed on the 660B CRT are functions derived from averaged data. Included among these functions are:

a. Coherence (COH)

b. Transfer Function (TF)

c. Transmissibility (TM)

d. Coherent Output Power (COP)

e. Cross Correlation (CC)

f. Auto Correlation (AC)

g. Impulse Response (IR)

h. RMS Spectrum

i. Cumulative Distribution

For example, the coherence function is derived using the power spectrum data from Channels A and B and the CO and QUAD components of the cross spectrum. In fact, functions "a" thru "h" make use of one or more of the four averaged spectrum data. Function "i" is derived from the averaged probability density function. These derived data are not available to the interface unless transferred to the display buffer memory first. If the data is not transferred, the user will have to take the averaged buffer data and perform the calculations outside the instrument.

b. Derived Data Equations - This section will describe how the derived functions are calculated within the analyzer from the "raw" averaged data.

| | | |
|---|---|---|
| $T_A$ | = Averaged Time Channel A | = Buffer 4 and 5 |
| $T_B$ | = Averaged Time Channel B | = Buffer 6 and 7 |
| $P_A$ | = Power Spectrum Channel A | = Buffer 4 |
| CO | = Colinear Component of Cross Spectrum | = Buffer 5 |
| QUAD | = Quadrature Component of Cross Spectrum | = Buffer 6 |
| $P_B$ | = Power Spectrum Channel B | = Buffer 7 |
| N | = 1 for Peak and Exponential | = N number of averages for summation. |
| $F^{-1}$ | = Inverse Fourier Transform | |
| * | = Can be transferred to Display Memory | |

*Power Spectrum Channel A = $\frac{P_A}{N}$

*Power Spectrum Channel B = $\frac{P_B}{N}$

RMS Spectrum Channel A = $\left[\frac{P_A}{N}\right]^{1/2}$

RMS Spectrum Channel B = $\left[\frac{P_B}{N}\right]^{1/2}$

Cross Spectrum

*a. Real = $\frac{CO}{N}$

*b. Imaginary = $\frac{QUAD}{N}$

c. Magnitude = $\frac{(CO^2 + QUAD^2)^{1/2}}{N}$

d. Phase = $\text{Tan}^{-1}\left[\frac{QUAD}{CO}\right]$

Averaged Transfer Function (TF)

*a. Real = $\frac{CO}{P_A}$

*b. Imaginary = $\frac{QUAD}{P_A}$

c. Magnitude = $\left[\frac{(CO^2 + QUAD^2)}{P_A^2}\right]^{1/2}$

d. Phase = $\text{TAN}^{-1}\left[\frac{QUAD}{CO}\right]$

*Average Transmissibility (TM) = $\left[\frac{P_B}{P_A}\right]^{1/2}$

*Can be transferred to Display Memory.

*Average Coherence (COH) = $\frac{CO^2 + QUAD^2}{P_A \cdot P_B}$

*Average Time Channel A = $\frac{T_A}{N}$

Average Time Channel B = $\frac{T_B}{N}$

*Average Coherent Output Power (COP) = $\frac{CO^2 + QUAD^2}{N \cdot P_A}$

Auto Correlation (AC) = $F^{-1}\left[\frac{P_A}{N}\right]$

Cross Correlation (CC) = $F^{-1}\left[\frac{CO + jQUAD}{N}\right]$

*Impulse Response = $F^{-1}\left[\frac{CO + jQUAD}{P_A}\right]$

*Can be transferred to Display Memory.

c. Scaling Formulas - To determine the scaled input value requires modifying the data according to the following equations. The abbreviation D will be used for the data portion of the equation. The definition of D is given in the cross reference table accompanying the equations, Figure 19-B where D is the raw data obtained directly from the appropriate 660B buffers.

S = Scaled Value

D = Data (See Figure 19-B)

$ATT_A$ = A/D Converter Full Scale, Channel A

$ATT_B$ = A/D Converter Full Scale, Channel B

$ATT_C$ = A/D Converter Full Scale, Current Channel (A or B)

$EU/V_A$ = Engineering Units/Volt, Channel A

$EU/V_B$ = Engineering Units/Volt, Channel B

$EU/V_C$ = Engineering Units/Volt, Current Channel (A or B)

R = Relative Factor

N = Number of Averages Completed
1 for EXP or PEAK Averaging

$\beta$ = Noise Bandwidth of Analysis Range if Normalized Per Hertz Otherwise, 1.0
Noise Bandwidth = 1.0 * Cell Width if Flat Weighting
1.944 * Cell Width if Hanning Squared Weighting

$\omega$ = Frequency of Data Point in Radians/Sec

W = Weighting Factor: 2.0 - Flat Weighting
1.333 - Hanning Squared Weighting
4.0 - Correlation Mode Window

EQ = Equalization Factor (Transfer Functions Only)

$$\frac{\text{Transfer Function (Current)}}{\text{Transfer Function (Stored)}}$$

$n_C$ = Number of Differentiations Performed on the Current Channel
0 = No Differentiation
Negative = Indicates Integration

$n_A$ = Same for Channel A

$n_B$ = Same for Channel B

$T_2$ = DRT Factor: 1 = No Translation
2 = In Translation

$T_4$ = DRT Factor: 1 = No Translation
4 = In Translation

NOTE: THE RELATIVE FACTOR AND THE ENGINEERING UNITS/VOLT ARE MUTUALLY EXCLUSIVE.

FORMULAS:

1. INPUT TIME DATA: $S = D * ATT_C * EU/V_C * R$

2. AVERAGED TIME DATA: $S = D * ATT_C * EU/V_C * R * \frac{1}{N}$

3. RMS SPECTRUM:

$$S = \sqrt{D} * \frac{ATT_C}{\sqrt{2}} * EU/V_C * R * W * [(j\omega)^{n_C}] * \frac{1}{\sqrt{\beta}} * \frac{1}{\sqrt{N}} * T_2$$

4. POWER SPECTRUM:

$$S = D(\frac{ATT_C}{2})^2(EU/V_C)^2 * R * W^2 * [(j\omega)^{2n_C}] * \frac{1}{\beta} * \frac{1}{N} * T_4$$

5. INSTANTANEOUS SPECTRUM:

$$S = D \frac{ATT_C}{\sqrt{2}} * EU/V_C * W * R * [(j\omega)^n] * \frac{1}{\sqrt{\beta}} * T_2$$

6. CROSS SPECTRUM:

$$S = D * \frac{ATT_A}{\sqrt{2}} * \frac{ATT_B}{\sqrt{2}} * EU/V_A * EU/V_B * W^2 * R * \frac{1}{\beta} * |(j\omega)^{n_A+n_B}| * \frac{1}{N} *$$

7. TRANSFER FUNCTION:

$$S = D * \frac{ATT_B}{ATT_A} * \frac{EU/V_B}{EU/V_A} * |(j\omega)^{n_B-n_A}| * R * EQ$$

FORMULAS (Con't.):

8. COHERENCE: $S = D$

9. COHERENT OUTPUT POWER:

$$S = D * \frac{ATT_B}{\sqrt{2}}^2 * (EU/V_B)^2 * W^2 * \frac{1}{\beta} * |(j\omega)^{2n_B}| * R * \frac{1}{N} * T_4$$

10. TRANSMISSIBILITY:

$$S = D * \frac{ATT_B}{ATT_A} * \frac{EU/V_B}{EU/V_A} * |(j\omega)^{n_B - n_A}| * EQ$$

11. PROBABILITY DENTSITY:

$$S = \frac{64}{ATT_C} * \frac{1}{EU/V_C} * R * D$$

12. IMPULSE RESPONSE:

$$S = D * \frac{ATT_B}{ATT_A} * \frac{EU/V_B}{EU/V_A} * |(j\omega)^{n_B - n_A}| * EQ * T_4$$

13. CROSS CORRELATION:

$$S = D * \frac{ATT_A}{\sqrt{2}} \times \frac{ATT_B}{\sqrt{2}} * EU/V_A * EU/V_B * W^2 * R * \frac{1}{N} * |(j\omega)^{n_A + n_B}| * T_4 * .25$$

14. AUTO CORRELATION:

$$S = D * ATT_C * EU/V_C * (W)^2 * \frac{1}{N} * |(j\omega)^{2n_C}| * R * T_4$$

| FUNCTION | BUFFER NUMBER | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0[1] | 1 | 4 | 5 | 6 | 7 | 8 | 9 | A[3] | B | E[1] |
| INPUT TIME | FRONT PANEL SETTING | NONVOL-ATILE | 2 | 2 | 2 | 2 | TIME[6] | TIME[6] | DISPLAY MEMORY STATUS | TEXT STRING | AVERAGE STATUS |
| AVERAGE TIME | | | A TIME | A TIME | B TIME[4] | B TIME[4] | TIME[6] | TIME[6] | | | |
| INST SPECTRUM | | | 2 | 2 | 2 | 2 | SEE EXCERPT | | | | |
| RMS SPECTRUM | | | $P_A$ | CO[4] | QUAD | $P_B$ | $P_A$ | $P_B$ | | | |
| POWER SPECTRUM | | | $P_A$ | CO[4] | QUAD | $P_B$ | $P_A$ | $P_B$ | | | |
| CROSS SPECTRUM | | | $P_A$ | CO | QUAD | $P_B$ | CO | QUAD | | | |
| TF | | | $P_A$ | CO | QUAD | $P_B$ | $TF_R$ | $TF_I$ | | | |
| TM | | | $P_A$ | CO | QUAD | $P_B$ | TM | 2 | | | |
| COH | | | $P_A$ | CO | QUAD | $P_B$ | COH | 2 | | | |
| COP | | | $P_A$ | CO | QUAD | $P_B$ | COP | 2 | | | |
| IMPULSE RESP. | | | $P_A$ | CO | QUAD | $P_B$ | IMP RESP | 2 | | | |
| CROSS CORR. | | | $P_A$ | CO | QUAD | $P_B$ | CO | QUAD | | | |
| AUTO CORR. | | | $P_A$ | CO | QUAD | $P_B$ | $P_A$ | $P_B$ | | | |
| PROB. DENSITY | ▽ | ▽ | A PROB DENSITY | B PROB DENSITY | 2 | 2 | A PROB DENSITY | B PROB DENSITY | ▽ | ▽ | ▽ |

[1]These buffers are always needed to correctly interpret the Averager buffers (4, 5, 6, 7).
[2]This buffer has no data pertaining to this function.
[3]This buffer is always needed to correctly interpret the Display Memory buffer (8, 9).
[4]In the 2K mode, this buffer contains the second half of the channel A data.
[5]The phase is equal to: [(decimal value) - 16384] * 0.01098632813
[6]These buffers have the Time data for either channel A or B.

TABLE 19-14B. CROSS REFERENCE, CONTENTS OF 660B BUFFERS

EXCERPT

(INSTANTANEOUS SPECTRUM ONLY)

| FUNCTION | 8 | 9 |
|---|---|---|
| CHANNEL A & B REAL | A REAL | B REAL[4] |
| CHANNEL A & B IMAG | A IMAG | B IMAG[4] |
| CHANNEL A & B MAG | $\sqrt{A_R^2 + A_I^2}$ | $\sqrt{B_R^2 + B_I^2}^4$ |
| CHANNEL A & B PHASE | A PHASE[5] | B PHASE[4,5] |
| CHANNEL A OR B | REAL | IMAG |

[1]These buffers are always needed to correctly interpret the Averager buffers (4, 5, 6, 7).
[2]This buffer has no data pertaining to this function.
[3]This buffer is always needed to correctly interpret the Display Memory buffer (8, 9).
[4]In the 2K mode, this buffer contains the second half of the channel A data.
[5]The phase is equal to:
[(decimal value) - 16384] * 0.01098632813
[6]These buffers have the Time data for either channel A or B.

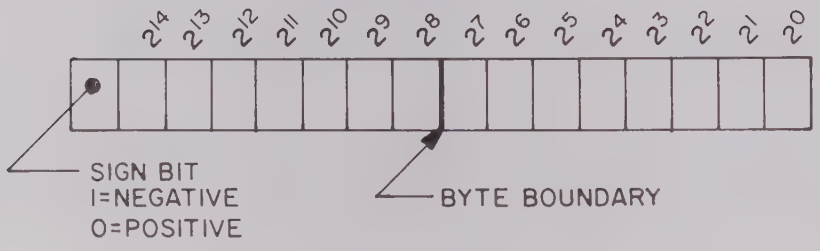
TABLE 19-14B. EXCERPT FOR CROSS REFERENCE, CONTENTS OF 660B BUFFERS

## INTERNAL NUMBER FORMATS

### 8-BIT INTEGERS

RANGE 0 TO 255 ($2^8-1$)

### 16-BIT INTEGERS




RANGE $-32{,}768\ (-2^{15})$ TO $+32{,}767\ (2^{15}-1)$

### 3 BYTE FLOATING POINT NUMBERS

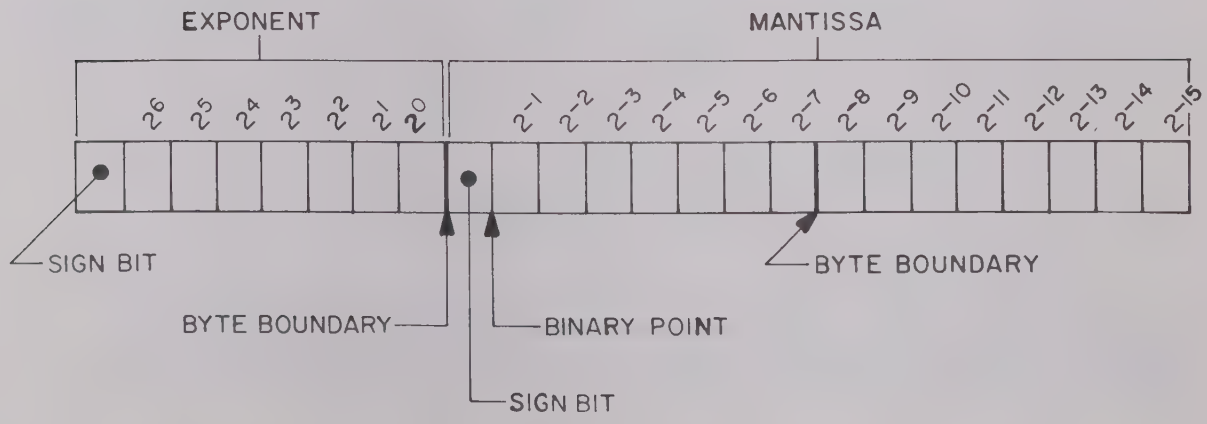



FIGURE 19-15. INTERNAL NUMBER FORMATS

B. Internal Data Formats

Data in the 660B is stored in various formats. It is assumed that the reader is familiar with Radix 2 to Radix 10 conversion. The features of each format follow:

1. 8-Bit Bytes - This is the simplest format. Each byte represents an unsigned, positive integer in binary format. Since a byte consists of 8 bits, the range of numbers is 00000000 to 11111111.

2. 16-Bit Integers - This format groups two bytes together to form one 16-bit binary number. The numbers are stored in two's complement form. The most sigfnificant bit (MSB) of each number is the sign bit. If the MSB is zero, the number is positive and the remaining 15 bits are interpreted as a binary number in the usual manner. If the MSB is one, the number is negative. To determine the absolute value, the number must be two's complemented. For example, consider the negative number 11------110101. To find the absolute value, complement each bit 00------001010. And, add one to the result 00-----001011. Since this bit pattern represents the decimal number 11, 11------110101 represents -11.

3. 40-Bit Scaled Integers - This format is simply a number, multiplied by 100,000, converted to binary. Resolution is always 1/100,000. Full two's complement. To decode, divide by 100,000.

4. 3 Byte Floating Point Numbers - To provide for a large range of numbers and to allow for fractional quantities, a floating point format is used for most of the data in the 660B. Numbers in this format consist of 3 bytes; the first byte is the characteristic in two's complement format. The second and third byte form a 16-bit mantissa. The mantissa is in a normalized two's complement format with the binary point after the most significant bit. Hence, the range of positive mantissas is 1/2 (0100------00) to 1-1/16,324 (011------11) and the range of negative mantissas is -1 (10------00) to -(1/2 + 1/16,234) (1011 ------11). The only mantissa which is not normalized and not in one of these ranges is zero (16 zero bits).

The value represented by a floating point can be found by using the relationship:

$$\text{Value} = \text{Mantissa} \times 2^{\text{Characteristic}}$$

In the following example, the bit patterns are represented as hexidecimal digits to avoid the appearance of many ones and zeroes. These examples indicate the conversion process for the four possible kinds of floating point numbers.

a. Positive Mantissa and Positive Characteristic - An example of a floating point number with a positive mantissa and a positive characteristic is 02 60 00. The MSB of the characteristic (02) is zero, so the value is +2. The MSB of the mantissa is zero, so the mantissa is positive and its value is $2^{-1} + 2^{-2} = .5 + .25 = .75$. Therefore, the number is $.75 \times 2^2 = 3$.

b. Positive Mantissa and Negative Characteristic - A positive mantissa and a negative characteristic will yield a positive number which is always less than one. For example, FE 06 00 has a negative characteristic, since the MSB is one. The absolute value of the characteristic is 2, found by taking the two's complement of FE. Hence, the value of the number is $.75 \times 2^{-2} = 3/4 \times 1/4 = 3/16$.

c. Negative Mantissa and Positive Characteristic - The sign of a floating point number is determined by the sign of the mantissa. A negative mantissa with a positive characteristic is a negative number whose absolute value is greater than or equal to one. Since the MSB of the mantissa 02 A0 00 is one, the mantissa is negative. Taking the two's complement of the mantissa yields 02 60 00. Since this number equals 3 as previously shown, 02 A0 00 = -3.

d. Negative Mantissa and Negative Characteristic - Negative numbers with absolute values less than one can be represented using a negative mantissa and a negative characteristic. The value of FE A0 00 can be found by taking the two's complement of both the exponent FE (02) and the mantissa A0 00 (60 00). This number, then is $-.75 \times 2^{-2} = -3/4 \times 1/4 = -3/16$. Other examples of floating point numbers follow:

| | |
|---|---|
| 00 00 00 | Zero, the only number with an unnormalized mantissa |
| 80 40 00 | The smallest possible positive number, equal to $2^{-1} \times 2^{-128}$ |
| 7F 7F FF | The largest possible positive number, equal to $(2^{-1} + 2^{-2} + 2^{-3} \text{ ---} +2^{-15}) \times 2^{127}$ |
| 7F 80 00 | The negative number with the largest absolute value, equal to $-1 \times 2^{127}$ |
| 80 BF FF | The negative number with the smallest absolute value, equal to $-(1/2 + 1/16{,}324) \times 2^{-128}$ |
| 01 40 00 | Equal to one, $1/2 \times 2^1$ |

C. I/O Formats

1. Selecting Formats and Blockfill

Three formats are provided to allow flexibility during I/O and external data manipulation. The format is selected using the 30 series of DEFine AUX. In addition, this DEFine AUX series determines if blockfill is to be used on output. See section, "DEFine AUXiliary Selectable Parameters," Section 19.2, Paragraph A.

Blockfill is used in conjunction with the blocksize to determine the number of bytes to output. If the number of data bytes in a block is less than the blocksize, a number of fill characters equal to the difference between the blocksize and the number of data bytes is output. For example, if the blocksize has been set as 72 and there are 70 data bytes in a particular block, then 70 bytes will be output by the 660B if no blockfill is selected. If blockfill is selected, an additional two characters will be output by the 660B.

The blockfill filler characters are blanks if the format is ASCII and nulls if the format is binary. Blockfill is optional only on output. On input to the 660B, all buffers must be blockfilled. The last block need not be blockfilled if one of the following conditions exist:

a. Input is taking place over the IEEE-488 interface and the EOI line is used to signal the end of the transfer, or

b. If the format is ASCII, and EOT (control D) byte may be used to signal the end of the transfer when using either the RS232-C or IEEE-488 interfaces.

2. Binary Format

This is the simplest format. Each internal data byte is simply copied to the appropriate interface on output. On input, a byte entered from the interface in use is copied into the appropriate byte in the data buffer. This format provides the fastest I/O time and most compact means of externally storing data. Binary format is selected by entering the sequence 34 SET DEF AUX. Output blockfill, if used, (35 SET DEF AUX) uses nulls as fill characters on the last block.

3. Hexadecimal ASCII

This format is the next level up in complexity from binary format. It is useful in systems where the RS232-C parity cannot be turned off as it must be to successfully transmit 8-bit data in binary format. In hexadecimal ASCII format, each byte is split in half. Each half byte is then converted to a hex digit and the ASCII equivalent for each digit is output over the interface. For example, the byte 1010 0011 would be output as the ASCII characters A 3.

Hexadecimal format is selected by the pushbutton sequence 32 SET DEF AUX. If 33 SET DEF AUX is entered, blanks will be used as blockfill in each buffer.

On input, all characters other than hex digits 0-9 and A-F are ignored, except for an EOT (control D) which terminates the input. The hex digits may be separated at any point by as many other characters, usually blanks as the user desires. Splitting the two characters associated with one byte across a block boundary is not allowed and results in an I/O non-recoeverable error. The message BYTE SPLIT ACROSS BLOCK is displayed in the entry field. For example, if the blocksize is 13 and the characters 0 1 2 3 4 5 6 7 8 9 A B C 0 1 2 3 4 5 6 7 8 9 A B 0 are input, this error will result because the digit C is the last character of the first 13 byte block and 0 is the first character in the next block.

The internal format of data has no effect on the output when binary or hexadecimal ASCII format is in use. Each internal byte is simply output over the interface. Similarly on input, bytes are received from the interface, converted from hexadecimal ASCII if necessary, and stored in the next appropriate location. If one of these formats is used, the user must be cognizant of the internal format in order to interpret the data and manipulate it properly.

4. Decimal ASCII

If the sequence 30 SET DEF AUX is entered, decimal ASCII format is selected. Unlike binary and hexadecimal ASCII format, the characters output by the 660B depend on the internal format. If the internal format is 8-bit bytes, each byte is converted to a decimal number 0 to 255 and these digits are output in ASCII in a 4 character field padded on the left with as many blanks as required. For example, the decimal number 27 would be output as ØØ27 where Ø=blank.

If the data buffer contains 16-bit integers, each datum, 2 bytes, is converted to a decimal -32768 to 32767 and these digits are output in ASCII in an 8 character field padded on the left with blanks. For example, the decimal number 1025 would be output as ØØØ1025.

Numbers represented internally as 3 byte floating point numbers are output in an ASCII exponential format in a 12 character blank filled field. The general format of this field is leading blanks, minus sign if the number is negative, 4 digits of mantissa with floating decimal point, and characteristic with sign. The decimal point is shifted prior to output so that the characteristic is always a multiple of three. A typical output of ØØØØ12.73+03 is $12.73 \times 10^3$ .

On input, a general format can be used to enter decimal ASCII numbers. All characters except for digits, signs, and decimal points are ignored and can be used as number separators. If integers are being entered, decimal points are considered number separators.

If too small or too large a number is entered, it is replaced by zero or the largest possible number of the correct sign, respectively. In addition, the message NUMBER RANGE is displayed in the cursor horizontal field. When the data buffer contains 8-bit integers, however, no error message is displayed and modulo 256 of the input is stored.

If a floating point data buffer is being input, exponential or fixed point formats may be used to enter the data. If exponential format is used, the following rules must be observed:

1. No separator characters may appear between the mantissa and the characteristic, and
2. The characteristic must be two digits.

Except for the rules mentioned above, decimal data may be entered in free format. For example, the sequences 1023 or +1.023+03 or 1023000-03 all input the number 1023. As with hexidecimal numbers, numbers may not be split across a block boundary. If split, the 660B will view the two halves of the number as two distinct numbers.

5. Output Terminators

When outputting ASCII data either hexadecimal or decimal over the RS232-C or IEEE-488 interfaces, the 660B may be requested to output terminating characters after each block. These characters are specified by the 50 series of DEFine AUX in Figure 19-3 and are not included in the blocksize. For example, if the blocksize is 72 bytes and 55 DEF AUX is specified, each block will contain 74 characters of which 72 are data bytes and one each for carriage return and line feed. The last block will contain 75 characters of which 72 are data bytes and one each for carriage return, line feed, and EOT.

On input, the setting of the 50 series of DEFine AUX is ignored. No terminating characters are allowed except EOT (CNTRL/D) which will terminate input even in the middle of a block.

NOTE: Output terminators can not be used in binary format.

D. Starting and Cancelling I/O

The following steps provide a check list and a summary of the procedures required to transfer data to and from the 660B.

1. Set hexadecimal switches on Executive Board for interface configuration desired. Press SYS RST.

2. Select parameters for data transfer.

   a. Set blocksize (1 to 2048 allowed).
   b. Select desired I/O format with or with out buffer fill on outputs.
   c. Select buffer terminators for output only.
   d. If data is output over RS232-C interface, determine if software handshake is necessary.

3. If the 660B is to output data, perform steps to have the 660B calculate data. If inputting data to the 660B, prepare data for transfer across the interface.

4. Initiate data transfer using one of the external I/O initiate commands.

5. At the conclusion of a successful data transfer, an ACK is issued over the interface, (see Section 19.2, Paragraph C, "Acknowledging Commands"). If a recoverable error occurred, a NAK is issued over the interface. Also, an error message is displayed in the cursor horizontal field. If a non-recoverable error occurred at any time, the I/O is terminated, and a rotating error message appears in the entry field. In addition, if the RS232-C is the active interface, a NAK is output. If the IEEE-488 is the active interface, a service request is issued and the non-recoverable I/O error bit pattern is set in the

5. (Con't.)

serial poll status byte. If this occurs, the 660B I/O section must be reset by pressing CRT ONLY pushbutton. A 488 bus controller can reset the I/O section by issuing the GO TO LOCAL command.

6. The user may cancel the I/O at any time by pressing the CRT ONLY pushbutton. If the front panel is locked out as it is with transfers of most data buffers, the CRT ONLY command can be sent over an interface, provided the data transfer is not taking place over the same interface.

E. Supplemental Data

The majority of the information which the 660B can provide is available from the data buffers by using the external I/O initiate commands. Two buttons, DISK and AUX, on the 660B provide for outputting additional data which may be useful in certain applications.

When the DISK pushbutton is used and the sequence SET DISK or RECALL DISK or CLEAR DISK is entered, the contents of the entry field preceded by an S, R, or Z are output over the IEEE-488 interface. Since the entry field is 14 characters long, 15 ASCII characters are output. This output is useful for determining if the 660B has responded properly to a remotely issued command sequence. Note, the following limitations apply:

1. Since the CLEAR pushbutton may blank out the entry field, the probable output using the sequence CLEAR/DISK is a Z followed by 14 blanks.
2. The 660B will output a lower case d as a dollar sign $.

The second source of supplemental data is the AUX pushbutton. The data output by this pushbutton is determined by the zero series of DEFine AUX, see "DEFine AUX Selectable Parameters," Section 19.2, Paragraph A. The default output of the AUX pushbutton is the ASCII character string necessary to generate a plot on the 134A and 136A Digital Plotters. This output occurs over the RS232-C interface.

AUX 2 provides for plot output over the 488. The output is the sames as AUX 1 (the default) would send over RS232-C, but the last byte is sent with an EOI. All outputs over 488 end with an EOI on the last byte.

If the sequence 0 SET DEF AUX is entered, pressing the AUX pushbutton will cause the analog X-Y Plotter connectors J118, J119, and J120 to output the voltages corresponding to the point on the display indicated by the cursor. This REST AT CURSOR mode can be used, for example, to record the time history of the amplitude at a particular frequency on a strip chart recorder.

AUX 3 and 4 provide for outputting the cursor fields over the RS232-C and the IEEE-488 (1978) interfaces, respectively. In these modes the data which is output over the appropriate interface is the entry field, the cursor horizontal field, and the upper cursor amplitude field, in that order. The data is output in ASCII format; the same characters which are displayed on the CRT are output over the interface except for the lower case d which is output as a dollar sign $. The length of the fields is 14 bytes each. If a field is blank, a number of blanks equal to the length of that field are output. In addition, each field is terminated with the characters specified by the current setting of the 50 DEFine AUX series.

As with any I/O, any AUX pushbutton output may be cancelled by depressing the CRT ONLY pushbutton in the OUTPUT TYPE section of the 660B.

Additional supplemental data may be obtained from the 660B status byte. The format of this byte and the commands to cause its output are discussed in the "Additional Remote Commands," Section 19.2, Paragraph C.

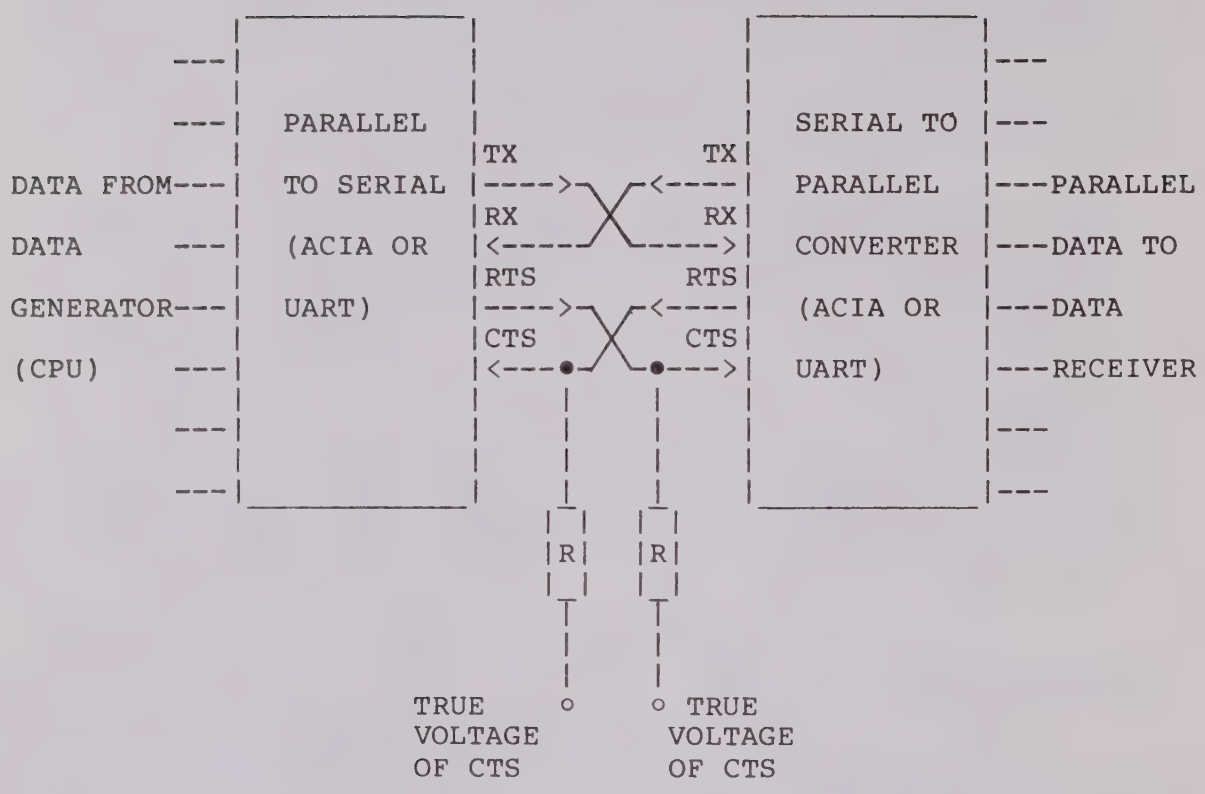
## 19.4 Connecting to the Interfaces

In this section, the details of connecting to each interface are discussed. A list of signal names and pin assignments for each interface is contained in the Appendix, Section 19-5, and should be referenced in conjunction with this section when fabricating the interface cables.

### A. RS232-C

Perhaps the simplest interface to implement from a hardware viewpoint is the RS232-C interface. Figure 19-16 illustrates a typical interconnection between two devices. The data transfer takes place over two wires. Each device has a data out port (TX) anda data in port (RX) and the TX port of one device is connected to the RX port of the other.

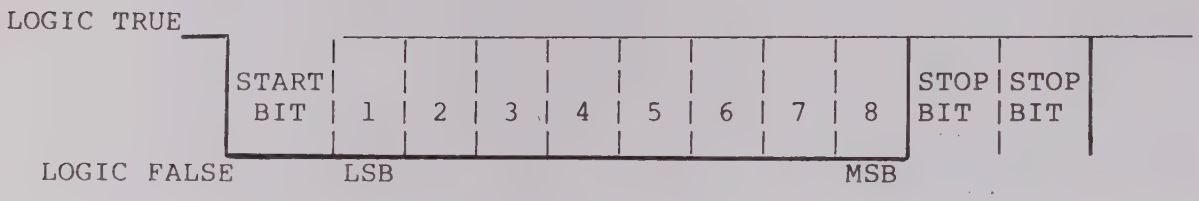
Data from the sender is presented, usually in 8-bit bytes, to the parallel-to-serial converter. The converter sends the byte out the TX port, one bit at a time, LSB first as shown in Figure 19-17. When no data is being transmitted, the logic




TX = TRANSMIT DATA
RX = RECEIVE DATA
RTS = REQUEST TO SEND
CTS = CLEAR TO SEND
R = RESISTOR

FIGURE 19-16. RS232 INTERFACE

ASYNCHRONOUS DATA FORMAT




-15V ≤ LOGIC TRUE ≤ -3V  -12V TYPICAL
+3V ≤ LOGIC TRUE ≤ +15V  +12V TYPICAL

FIGURE 19-17

true level is sent. A start bit, a logic false level of one bit width in duration, precedes each character. The character is terminated by one or two stop bits, a logic true level of one bit width in duration. Two stop bits are used at 110 baud and one stop bit is used all other baud rates.

In addition to the data bits, a parity bit may be added between the last data bit and the first stop bit. The parity bit is selected so the number of data bits which are logic true (1) is even or odd, depending on which parity is selected. The RS232-C interface to the 660B always uses 8 bits. When the hexadecimal switches on the Executive Board indicate that no parity is desired, or when a binary format I/O is in progress, the 8 bits with no parity mode is used. In all other cases, the 7 bits plus parity bit mode is used.

A hardware handshake is provided on the RS232-C interface using the request to send (RTS) and clear to send (CTS) lines. The receiver asserts RTS when it is ready to receive data. When the CTS input to the sender is asserted, usually because it is tied to the receiver's RTS line, the sender may output data.

In the 660B, the CTS line is connected through a resistor to the logic true voltage level (-12 volts). If the user's application does not require the use of this handshake signal, it need not be connected.

Handshaking of the data sent to the 660B is provided under software control. If commands are being sent to the 660B over the RS232-C interface, the sender should wait for an ACK or a NAK character before sending the next command character. (See "Acknowledging Commands, " Section 19.2, Paragraph C.) When data is being input to the 660B, the sender must wait for a ready character SYN (control V) from the 660B before inputting each block of data, with a block being the number of characters specified by the blocksize.

On output, the 660B will wait for a SYNC (control V) to be input before outputting each block. Since it may not be necessary to use this software handshake on output, either because the CTS line is used or because the receiver is a fast device, the wait for ready character may be turned off by entering the sequence 60 SET DEF AUX. After completion, the subsequent data outputs on the RS232-C interface will begin as soon as the 660B is ready to output the data. The wait for SYN (control V) is not used when outputting a status byte or for any output initiated by pressing the AUX button.

## B. IEEE-488

### 1. Devices and Interface Lines

The IEEE-488 interface provides a means of communication among several devices in the laboratory situation. The interface is usually controlled by a device which is the bus controller. While more than one device on the bus may be capable of being controller, only one controller may be active at any time. The remaining devices on the bus may be set up by the controller to be talkers or listeners. The programming for the controller should include information about the capabilities for each device, whether the device is capable of being a talker, listener, or both.

### 2. Hardware Overview

The IEEE-488 interface consists of 16 lines, 8 of which are data lines, 3 lines which are handshake signals (byte transfer control), and 5 lines which are interface management signals. See Figure 19-18. The data lines which make up the 488 data bus DI01 to DI08, are used to pass both data and bus commands. The attention line (ATN) determines how the data lines are to be interpreted. If ATN is not asserted, the data lines are interpreted as data usually being sent from a talker to one or more listeners. If ATN is asserted, the data lines are interpreted as bus commands being sent from the controller to all other devices on the bus. When ATN is asserted by the controller, all devices must clear the bus within 200 nanoseconds.

One of the main features of the IEEE-488 interface is the unique handshake provided by the three transfer control signals. The three transfer signals are data available (DAV), not ready for data (NRFD), and not data accepted (NDAC). In any byte transfer, the source controls the DAV line and the acceptors control the NRFD and NDAC lines.

Figure 19-19 illustrates a typical byte transfer between a source and one or more acceptors. The asserted or true state of all signals on the 488 bus corresponds to a voltage level less than 0.8 volts and the false state corresponds to a voltage level greater than 2.0 volts. The acceptors assert NDAC, while the source indicates that the data is not available. The source places a byte of data on the data lines and waits a

# TYPICAL IEEE—488 BUS CONFIGURATION

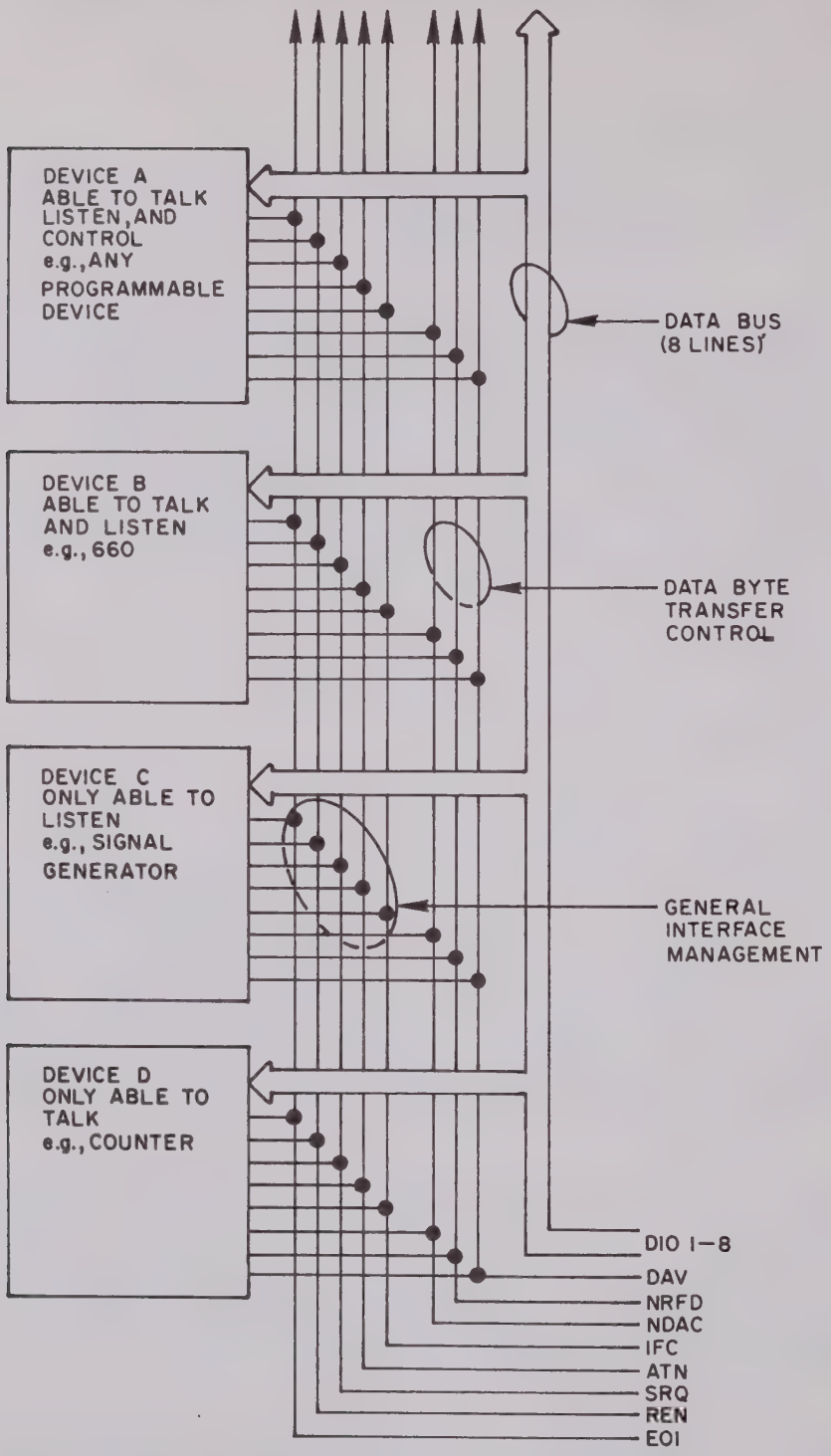
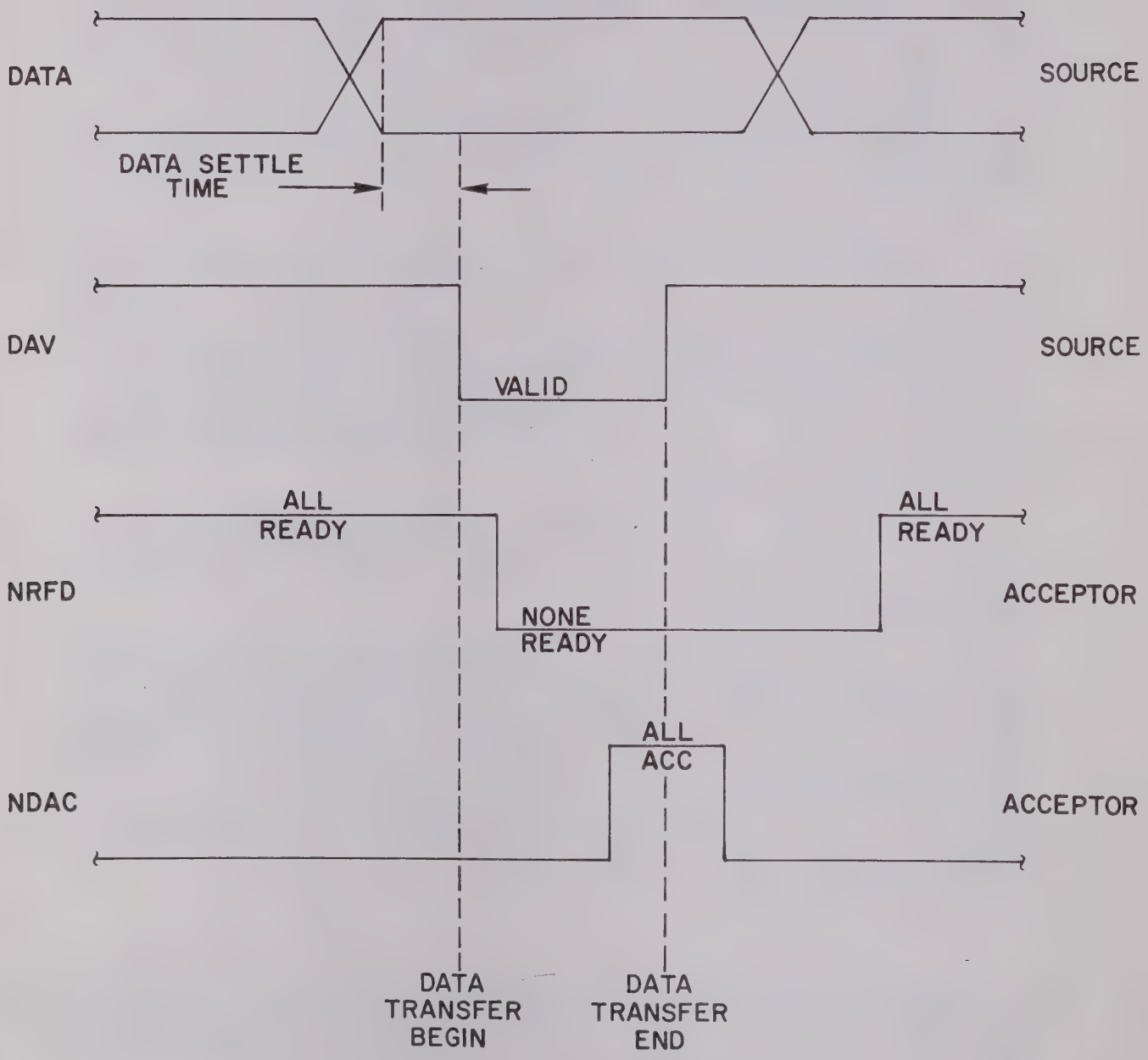



FIGURE 19-18

## IEEE—488 INTERFACE
## SOURCE AND ACCEPTOR HANDSHAKE




〈 0.8 VOLTS = LOGIC TRUE
〉 2.0 VOLTS = LOGIC FALSE

FIGURE 19-19

minimum of 2 microseconds for the data to settle. When all the acceptors are ready as indicated by a false value of the NRFD line, the source starts the data transfer by asserting DAV. The acceptors then assert NRFD and begin copying the byte from the data lines into their internal buffer. As each acceptor completes the data transfer, it drives NDAC to its false level.

As long as any acceptor is asserting NDAC, the line remains low. Therefore, the data transfer rate is determined by the slowest device taking part in the transfer. When the last acceptor receives the byte, NDAC is no longer asserted. The source, sensing that the byte has been accepted by all, drives DAV to the false level and begins changing the data lines for the next byte transfer. When DAV goes false, the acceptors drive NRFD to the false state and the source may begin the next byte transfer.

The end or identify line (EOI) may optionally be used by a talker to indicate that the current byte is the last byte of the transfer. When the 660B is a talker, EOI is asserted as the last byte of the transfer is output. When the 660B is a listener and a data buffer input is in progress, asserting EOI will terminate the input. For example, the 660B will assume no more data is forthcoming and will interpret subsequent bytes as remote commands. When remote commands are entered via the IEEE-488 interface, that is a data transfer is not taking place, the EOI line is ignored.

The EOI signal assumes the meaning IDENTIFY when the controller asserts EOI and ATN simultaneously as part of the parallel polling sequence. The controller MUST NOT parallel poll with a 660B on the bus.

The remaining three interface lines provide additional communication between the controller and other devices on the bus. When the remote enable line (REN) is asserted, devices may respond to commands from the interface. The REN line is ignored by the 660B except in connection with the GTL command. Interface clear (IFC) is used by the controller to clear all use of the interface. All devices must respond within 100 microseconds. The service request line (SRQ) may be asserted by a device to indicate to the controller that service is required.

## 3. Introduction

The 660B implements the 1978 IEEE-488 specifications. It is assumed that the user is familar with the terms and nomenclature associated with the 488 bus. This manual is not intended to teach the user about the bus, but rather to clarify the software implementation which is not covered in any IEEE-488 specification.

Users interested in the controller mode of operation are advised to read the short section on no controller operation, as well.

a. Operation Without a 488 Bus Controller - This mode of operation is for use when only the 660B and one other device are on the bus. This mode is primarily for use with the 160 Data Recorder Adapter.

When the 660B hex switches are set for NO CONTROLLER, the 660B will make itself a listener on power up. If required to talk, it will make itself a talker for the duration of the transfer and then return itself to a listener. Whatever the 488 environment (reference Section 19-5, Appendix A) is set to in the software, SRQ's will not be issued. The 660B always concludes 488 output by asserting EOI with the last byte.

b. 660B Hardware Setup - The details of the settings of the hexidecimal switches mentioned above are explained in Section 19-2. For simplicity, the no controller mode may be selected by setting switch BE1 to 0. The 488 address has no meaning in the NO CONTROLLER mode.

If the settings of these switches are changed while the 660B is on, the 660B must be reset (SYS RST) to enable the change. The switch settings are read at reset/power up only.

c. Output Initiation from the 660B via the Front Panel - As mentioned above, the 660B will make itself a talker when required. The user may require the 660B to talk by use of the DISK pushbutton in the CALCULATION CONTROL group. When this button is depressed following a SET, RECALL, or CLEAR, the 660B must talk over the 488 bus.

The format of the output is a 15 character string with an EOI on the last character, namely:

```
SET    :   S
RECALL :   R   14 character entry/recall field
CLEAR  :   Z
           1      2-15
```

Two other pushbutton sequences also require the 660B to talk over the 488 bus:

1. AUX* — See Section 19.2
2. AUX*, PLOT / PLOT CAL — See Section 19.2

*Requires previous settings of DEF AUX

d. Output Initiation from 660B via Remote Control Commands - The 660B powers up as a listener to listen for remote control commands. Section 19.2 describes front panel buttons and switches and their remote control commands and describes the additional commands available only over the RS232 or IEEE-488 interfaces.

Two methods exist for getting the 660B to talk via these remote control commands:

1. Pushbutton Emulation - A device on the bus may be used to emulate a user depressing the pushbutton sequences previously mentioned. Section 19.2 illustrates all the remote commands associated with front panel controls. For convenience, some of the commands to emulate the pushbuttons are repeated below.

| Pushbutton | Remote Control Command |
|---|---|
| SET | S |
| RECALL | R |
| CLEAR | Z |
| DISK | Y4 |
| PLOT | Ø0* |
| PLOT CAL | Ø1* |
| AUX | Ø2* |

*Ø Letter O.

For example, if the 660B receives over the IEEE-488 (or RS232) interface the remote control sequence: SY4, (SET, DISK) the 660B will:

1) Place an S in the first location of the output buffer,

2) Copy the 14 characters currently in the entry/recall field into the output buffer locations 2->15, and

3) Become a talker on the IEEE-488 bus and issue the 15 characters over the bus, with an EOI on the last character.

2. Buffered I/O Output Command (?) - The output over the IEEE-488 command (?) is only receivable from the IEEE-488 or RS232 interfaces. Regardless of which interface issues the command sequence ?n, the 660B will become a talker

and output the data in the buffer n over the IEEE-488 bus. The buffer numbers indicated by n are described in Section 19.3. The details of buffered I/O are described in Section 19.3.

e. Operation with a 488 Bus Controller - This mode of operation is useful for controlling the 660B via the 488 bus. It is the only mode that will allow more than two devices to be connected to the bus without confusion. It is the only mode in which the 660B will respond to bus commands such as untalk, unlisten or serial poll. However, if the 160C and the 660B are to be the only devices on the bus and no external control is desired, a controller will serve no purpose. For many sequential control applications controller mode will not be necessary since the 660B will listen for commands without a bus controller.

If the 660B is informed via the hex switches that there is a bus controller on the 488 bus, it will assume that it must be given permission to use the bus. At power up, it is neither listener, nor talker. If addressed by the controller to talk or listen it will remain in that state until the controller changes its assignment.

The controller must be able to find out when the 660B would like to use the bus or is finished using the bus. The 660B leaves this information in the serial poll register. The content of the serial poll register is the serial poll status byte. The controller can get this byte at any time by serial polling the 660B. If the 488 environment is set so that updating the serial poll register issues a service request (SRQ), the 660B will update the serial poll register and turn on bit 6 of the serial poll status byte. This bit is the SRQ bit, its presence should be permitted to interrupt the controller. When the 660B issues an SRQ, it will wait for the controller to serial poll. This ensures that the controller will see every serial poll status byte before the 660B takes any further action. When the 660B is serial polled, the SRQ bit is removed from the serial poll status byte.

The 660B updates the serial poll register whenever the I/O is begun or finished over the 488 bus or when a command received over the 488 bus is unacceptable. The user may enable updates on other conditions and the issuance of SRQ's. For more information, see Section 19.5 Appendix C, Setting the 488 Environment. For the definition of the bit patterns that the 660B places in the serial poll register, see Section 19.5 Appendix A, Decoding the 660B's Serial Poll Status Byte.

f. Controller Limitations - Beware of the following when using a bus controller:

1. The controller must not parallel poll with a 660B on the bus! The hardware used to implement the 488 bus in the 660B will not properly decode a parallel poll. The 660B

response is unpredictable. Also, because of this, the parallel poll configure command is no longer recognized.

2. The controller must not serial poll when there is valid data on the bus that has not been accepted by all listeners. Some controllers automatically wait for the DAC line (or $\overline{\text{NDAC}}$) to go high. This wait is necessary because the device that is serial polled must place its serial poll status byte on the data lines. It is by definition the only talker and the controller is the only listener. If data were valid on the bus and not accepted when the serial poll active state was entered, that byte of data is lost. After the serial poll, the 660B is neither talker nor listener.

3. If the controller issues a GO TO LOCAL (GTL) command to the 660B, the 660B will respond as if the 660B command 03 (CRT ONLY) had been sent over the bus: it will reset its I/O drivers. This will terminate any I/O over either the 488 or the RS232 interfaces. When the I/O drives are reinitialized, the serial poll register will be updated with a byte to this effect. The 488 environment as set in the SRQ mask is not changed by the I/O reset. After the I/O drivers have been reset, whether by a GTL or an 03, the controller must remotely enable the 660B. Some controllers do this automatically as part of a high level language write statement.

g. Hardware Setup - The settings of the 660B internal hex switches are explained in Section 19-2. As shown in Figure 19-1 an example of correct settings of these switches (BC1, BE1, BG1, BJ1) would be:

| SWITCH | EXPLANATION |
|---|---|
| BC1 | Spare |
| BE1 | 9 |
| BG1 | C |
| BJ1 | No effect on 488 Bus |

This would set the 660B for: 488 address 7, controller mode, and even parity on the RS232 interface. The current system settings of these switches may be interrogated by depressing (SHIFT 2: 1, 2, 3, and 4) for baud rate, parity, 488 address, and controller, respectively.

Note that switch BG1 sets two bits of the 488 address and selects RS232 parity. To maintain the proper address, switch BG1 should be set for either C, D, or E to select even (shown), odd, or no parity on the RS232 interface.

The 488 address setting and the controller present bit must be correctly set for the 660B to accept addressed bus commands such as talk 7.

If the settings of these switches are changed while the 660B is running, it must be reset (SYS RST) for the changes to take effect. These switches are only read at reset/power up.

h. Software Setup - As mentioned previously, the user may enable optional updates of the serial poll register and/or the user may enable SRQ issuing on each update. Conditions that affect the 488 bus (I/O Request, I/O Complete, NAK) always update the serial poll register. For more information see the Appendices, Setting the 488 Environment, and Decoding the 660B Serial Poll Status Byte. If a controller is used that cannot be interrupted during a write statement, read the paragraph, Setting the 488 Environment.

The only other software setup required is that the 660B be "Remote Enabled". As previously mentioned, some controllers do this automatically as part of a write statement.

## C. J114 Control Interface

### 1. Control Inputs

Seventeen external control inputs are provided on the parallel interface connector (see Pin Assignments J114). To use these signals, which are equivalent to the similarly labeled front panel pushbuttons, the user must assert the desired line and pulse the input control data strobe pulse. In addition, all external control data lines not being used must be grounded. The lines must continue to be asserted until the 660B outputs a pulse on the Data Accept line. The one exception to this handshake is the system reset line. When this line is asserted, the 660B is reset immediately and no data strobe pulse is required.

### 2. Miscellaneous Output Signals

The miscellaneous output available on the parallel interface connector follows.

Block Sync Pulse - Pulsed high as an average is calculated on non-redundnat data in signal enhancement mode. This means, the entire input buffer contains different data since the previous block sync pulse.

### 3. J113 Parallel A/D Input

Little discussion has taken place regarding the A/D interface because unlike the other interfaces, the A/D interface can not be used to access the internal data buffers. The digital data entering the input buffer may be viewed, or the in-

ternal A/D's may be replaced by inputting digital time domain data into this interface. All signals are TTL. The true state is a high unless the signal name has a bar over it. Refer to Figure 19-19. When the A/D interface is used to output data from the internal A/D's, the data is presented on the 12 most significant bits of each channel's A/D data bus (bits 15 to 4). The data from the A/D's is in two's complement format and is interpreted as a fraction of the full scale indicated by the front panel input attenuator controls. This fraction can range from -1 (100000000000) to $1-2^{-12}$(011111111111). When the internal A/D's are used, bits 0 to 3 are tied to zero on the input to the input buffer. The AEOC line is pulsed high when the conversion is complete. As new data is presented on the data lines, AEOC may be used as a data available signal. This is true whether or not an external sampling signal is used.

To use an external sampling rate, the front panel FREQ/ORDERS switch must be placed in the ORDERS position and a sampling waveform is usually a sine wave with a frequency 2.56 times the highest frequency of interest. In this case, the frequency range switch selects the anti-aliasing filter to be used. The input sampling waveform must have a peak-to-peak voltage of at least 1 volt and less than 10 volts.

The A/D conversion cycle is started on the positive to negative transition through zero of the external sampling signal. The end of conversion is indicated by the AEOC signal.

To enter the external time domain data through the A/D interface, the following steps must be taken.

1. The external A/D enable line must be held low.

2. The data for channels A and B must be presented on the A/D bus in two's complement form with the most significant bit at 15. This A/D data is interpreted as a fraction of full scale indicated by the input attenuator control setting.

3. External conversion complete must be pulsed low to indicate when the next data word is available at the A/D connector.

4. If the data for a channel is less than 16 bits wide, the unused bits should be tied low.

FIGURE 19–20

A/D INPUT DATA (FOR REAL DATA) NO DRT

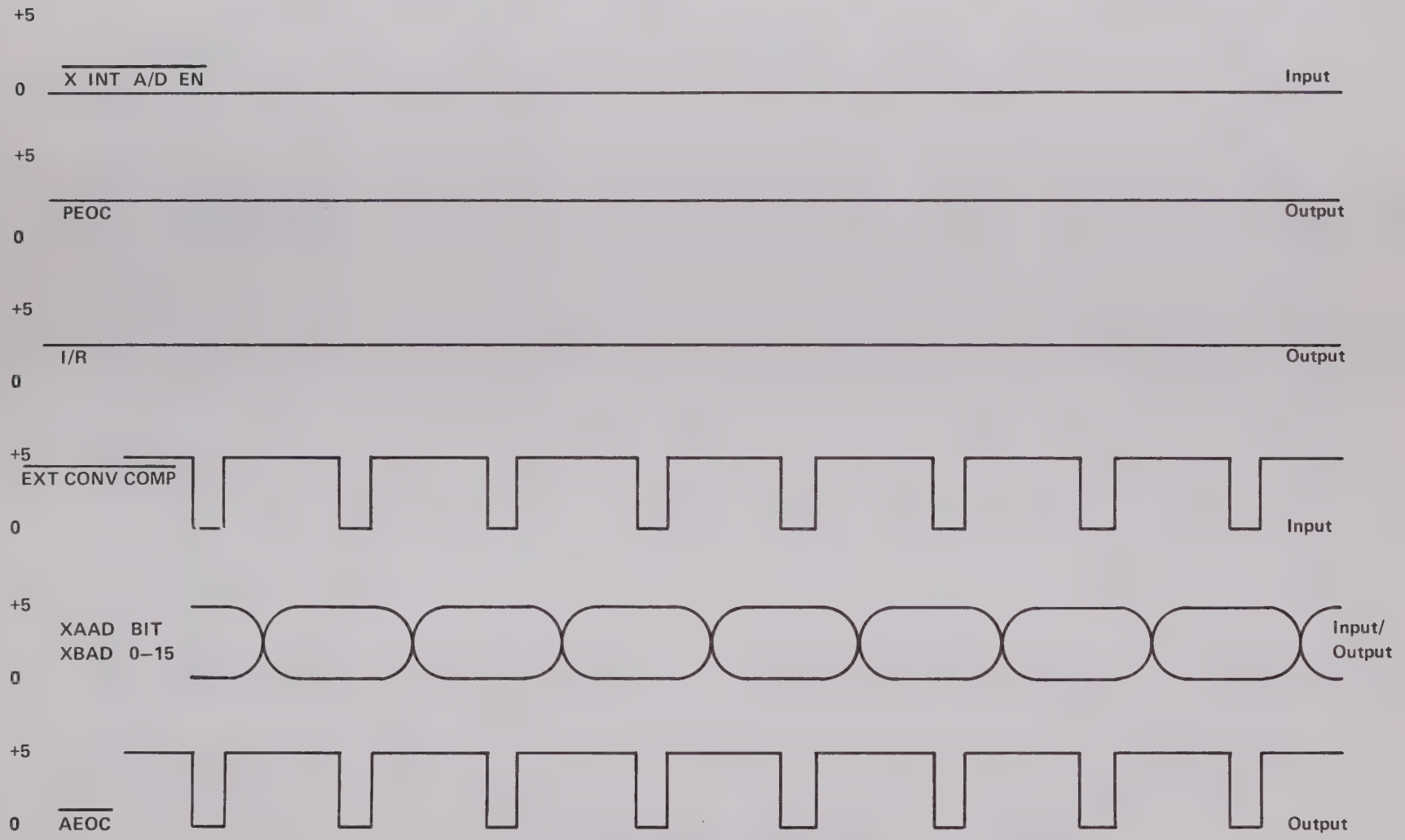
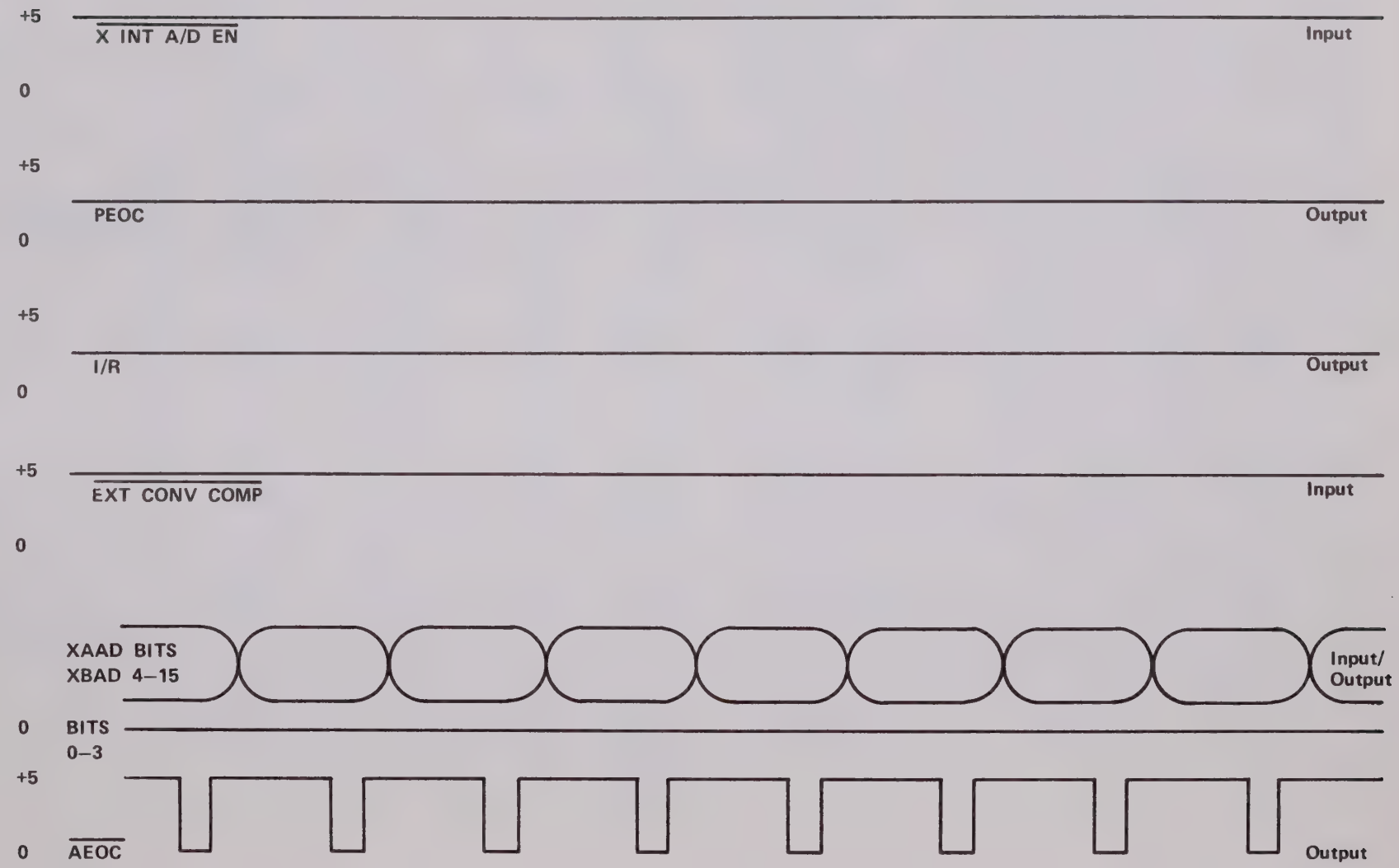


FIGURE 19–20 (Cont.)

A/D OUTPUT DATA (FOR REAL DATA) NO DRT



## 19.5 Appendix A

### A. Using the 660B with SRQ and Serial Poll

#### 1. Setting the 488 Environment

With the 660B in the controller mode (as set on the internal hex switches, see pages 19-3 to 19-7), the 660B can not make itself a talker or listener. The 660B must be instructed to be a talker or a listener by the controller. The controller serial polls the 660B for instructions and receives a serial poll status byte, contents of the serial poll register.

The following conditions always update the serial poll register:

1. Any I/O Type: Request, Completion, or I/O Has Been Reset
2. Either NAK: Command Not Acceptable, or I/O Must Be Reset

Other conditions may update the serial poll register. These can only be set from the interface using the SRQ mask as will be described below. The SRQ mask is also referred to as the 488 environment mask. Bit 6 of the SRQ mask controls whether or not each update of the serial poll register will issue an SRQ.

NOTE: IF SRQ'S ARE ENABLED, THE CONTROLLER MUST BE CAPABLE OF SERIAL POLLING.

The 660B will wait to be serial polled after posting an SRQ.

Controlling Serial Poll Register Updates and SRQ's

On power up, the 660B wakes up with the SRQ mask set to 0. This means that only required conditions update the serial poll register and these updates do not cause SRQ's. The following diagram explains the bits in the SRQ mask:

| Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Bit 0 Update on Averager ON/OFF 1=enabled
Bit 1 Spare
Bit 2 Update on ACK 1=enabled
Bit 3 Update on ARM ON/OFF 1=enabled
Bit 4 Update on HOLD ON/OFF 1=enabled
Bit 5 Update on PLOT ON/OFF 1=enabled
Bit 6 SRQ on every update of the serial poll word 1=enabled
Bit 7 Update on OVERFLOW ON/OFF 1=enabled

The SRQ mask may be set, recalled to the entry field, or cleared (set to zero) by the commands SWB, RWB, and ZWB. These commands may only be issued via the interfaces since no push-button corresponding to WB exists on the front panel. S, R, & Z correspond to SET, RECALL and CLEAR; WB is the function similar to the others in the CALCULATION CONTROL group.

For example, to get SRQ's only on required updates (I/O and NAKS), the controller sends the command string 64SWB. To get SRQs on required updates and averager on/off, the controller sends 65SWB. This should be interpreted as allowing averager on/off to update the serial poll register and SRQ on all updates.

Some controllers can not be interrupted by SRQ's during read and write statements, for example, the HP-9825. If this condition exists, and updates on ACKS with SRQ's enabled are desired, the 660B command output must be preceded by a "/". The slash is a one byte command equivalent to ZWB. If the "/" is omitted, the first byte of the output will produce an ACK SRQ from the 660B and the handshake will not be completed until the SRQ is responded to (serial polled). See Section 19-5. Since this controller can not be interrupted during a write, it will not serial poll until the write finishes. Therefore, the write will never finish.

For example, if this controller can not be interrupted, and if an SRQ mask of 68 has been established, the string 02 (press the AUX button) would hang. The string /0268SWB would turn off SRQ's, send the 02, and then re-establish the SRQ mask. Another solution would be having the controller output a byte at a time.

Note, that even if only one event causes updates, for example, averager on/off, other bits in the serial poll word will be correct when update occurs. That is, if the overflow bit is on in the serial poll word created by an update when the averager went off, an overflow did occur during the average even though that did not cause an update at that time.

In the above paragraph the word SRQ may be substituted for update in all cases to show what happens when bit 6 of the SRQ mask (SRQ on updates) is 1.

### 2. Decoding the 660B Serial Poll Status Byte

As described in the previous section, the controller may serial poll a 660B and obtain the serial poll status byte. The 660B places this byte in its serial poll register (an update) when a condition occurs that elicits a response from the controller. There are three types of conditions that may cause a serial poll register update. The type may be decoded from bits 1 and 2 of the serial poll status word:

```
Bit #    7   6   5   4   3   2   1   0

Bits 1 & 2 - Type of condition that causes
             this status byte to be created:
               00 Event Response
               01 I/O
               10 Spare
               11 Command Response

Bit 6      - Always reserved for SRQ Bit
               1 = Active Service Request
```

All event updates are optional, as is the acknowledge command response. If updates on these conditions are desired, each must be enabled as described in the previous section.

I/O and NAK updates are not optional.

For the 660B to post a service request (SRQ) on each update, see the previous section.

An explanation of each serial poll status byte follows.

a. Event Updates

There are ten events which cause an update of the serial poll status byte. These ten are the transition to ON and the transition to OFF of the following: averager, arm, hold, plot, and overflow.

The status of each one is represented by a bit in the event type serial poll status byte. For each, 1 = ON and 0 = OFF. The status shown by each bit will be correct even if that bit did not cause the update.

The event serial poll status byte is structured as follows:

```
Bit #    7   6   5   4   3   2   1   0

Bit 0      - Averager ON/OFF
Bit 1 & 2  - Event type status byte = 0
Bit 3      - Arm ON/OFF
Bit 4      - Hold ON/OFF
Bit 5      - Plot ON/OFF
Bit 6      - Reserved for SRQ bit
Bit 7      - Overflow ON/OFF*
             *Overflow is only cleared
              by starting the averager
```

Note that each condition is represented by the same bit in the status word as the bit that enables the update in the SRQ mask.

b. I/O Updates

Updates concerning the function of I/O are not optional. There is one special one, I/O Has Been Reset, which tells the controller that I/O has been terminated by CRT ONLY.

| Bit Pattern | 1 | X | 1 | 1 | 1 | 0 | 1 | 1 |
|---|---|---|---|---|---|---|---|---|
| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Bit 1 & 2 - I/O Type
Bit 6 - Reserved for SRQ bit

The controller must send the REMOTE ENABLE to the 660B at this point. Other I/O updates follow this pattern.

| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|

Bit 0 - 0 = Out, 1 = In
Bit 1 & 2 - I/O Type Update = 01
Bit 3, 4, & 5 - Type of I/O:
000 = General Buffer
001 = Disk Command
010 = AUX
011 = AUX Plot
111 = Reserved, See Above
Bit 6 - Reserved for SRQ bit
Bit 7 - 0 = Request, 1 = Complete

c. Command Response Updates

There are three possible command responses:

| | | |
|---|---|---|
| ACK: | Command Accepted: | 0X000110 |
| NAK: | Command Not Accepted: | 0X000111 |
| I/O MUST BE RESET: | I/O Must Be Reset: | 0X001111 |

| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|

Bit 0 - 0 = ACK, 1 = NAK
Bit 1 & 2 - Command Response = 11
Bit 6 - Reserved for SRQ bit

The ACK is optional. See the previous section to enable updates on ACKS. The Command Not Accepted NAK simply means that a command received could not be accomplished.

The I/O MUST BE RESET NAK means that everything coming in to the 660B on the 488 bus is considered invalid. This occurs if a 660B buffer is overrun. The controller response would be to send a GO TO LOCAL message and then remote enable the 660B again.

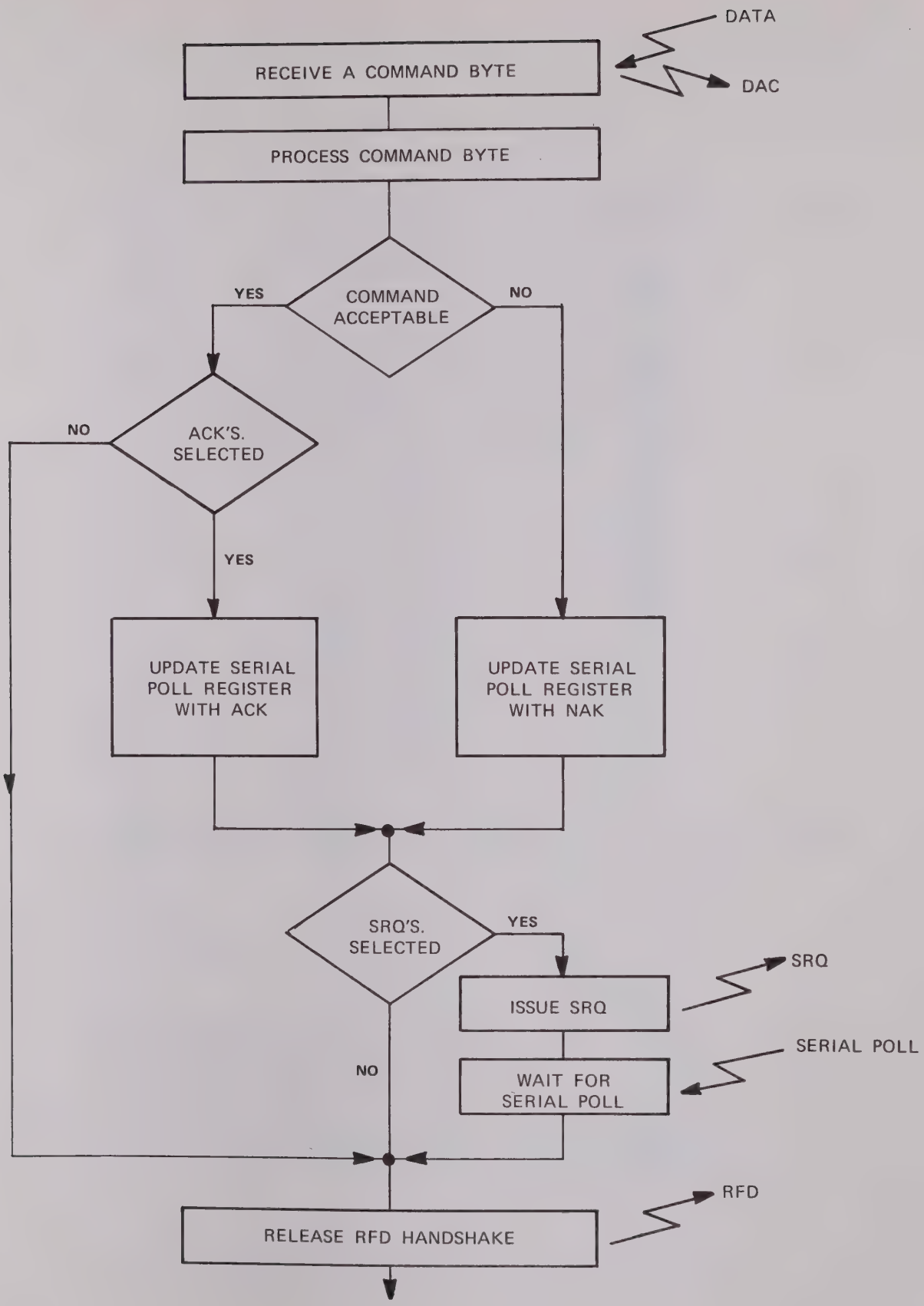



FIGURE 19-21. 660B RESPONSE TO COMMANDS RECEIVED OVER IEEE-488 INTERFACE

## 19.5 Appendix B

### B. Pin Assignments

#### 1. IEEE-488 (1978), J111

| Pin | Mnemonic | Comments |
|---|---|---|
| 1 | DI01 | Data Line 1 |
| 2 | DI02 | Data Line 2 |
| 3 | DI03 | Data Line 3 |
| 4 | DI04 | Data Line 4 |
| 5 | EOI | End or Indentify |
| 6 | DAV | Data Available |
| 7 | NRFD | Not Ready For Data |
| 8 | NDAC | Not Data Accepted |
| 9 | IFC | Interface Clear |
| 10 | SRQ | Service Request |
| 11 | ATN | Attention |
| 12 | SHIELD | |
| 13 | DI05 | Data Line 5 |
| 14 | DI06 | Data Line 6 |
| 15 | DI07 | Data Line 7 |
| 16 | DI08 | Data Line 8 |
| 17 | REN | Remote Enable |
| 18 | GRD-1 | Ground, (6) |
| 19 | GRD-2 | Ground, (7) |
| 20 | GRD-2 | Ground, (8) |
| 21 | GRD-2 | Ground, (9) |
| 22 | GRD-2 | Ground, (10) |
| 23 | GRD-2 | Ground, (11) |
| 24 | GRD-2 | Ground, LOGIC |

NOTE: 'Ground (n)' refers to the signal ground return of the reference contact.

#### 2. RS232-C, J112

| Pin | Mnemonic | Comments |
|---|---|---|
| 3 | TD | Transmit Data (from 660B) |
| 2 | RD | Receive Data (to 660B) |
| 4 | RTS | Request to Send (output) |
| 5 | CTS | Clear to Send |
| 8 | RLSD | Data Carrier Detect |
| 7 | GRD-3 | Data Common |
| 1 | CHASSIS GRD | |

3. Parallel A/D, J113

| Pin | Mnemonic | Comments |
|---|---|---|
| 1 | GRD-5 | |
| 26 | XBAD0 | External B CH A/D Data 0 |
| 2 | XBAD1 | External B CH A/D Data 1 |
| 27 | XBAD2 | External B CH A/D Data 2 |
| 3 | XBAD3 | External B CH A/D Data 3 |
| 28 | XBAD4 | External B CH A/D Data 4 |
| 4 | XBAD5 | External B CH A/D Data 5 |
| 29 | XBAD6 | External B CH A/D Data 6 |
| 5 | XBAD7 | External B CH A/D Data 7 |
| 30 | XBAD8 | External B CH A/D Data 8 |
| 6 | XBAD9 | External B CH A/D Data 9 |
| 31 | XBAD10 | External B CH A/D Data 10 |
| 7 | XBAD11 | External B CH A/D Data 11 |
| 32 | XBAD12 | External B CH A/D Data 12 |
| 8 | XBAD13 | External B CH A/D Data 13 |
| 33 | XBAD14 | External B CH A/D Data 14 |
| 9 | XBAD15 | External B CH A/D Data 15 |
| 34 | XAAD0 | External A CH A/D Data 0 |
| 10 | XAAD1 | External A CH A/D Data 1 |
| 35 | XAAD2 | External A CH A/D Data 2 |
| 11 | XAAD3 | External A CH A/D Data 3 |
| 36 | XAAD4 | External A CH A/D Data 4 |
| 12 | XAAD5 | External A CH A/D Data 5 |
| 37 | XAAD6 | External A CH A/D Data 6 |
| 13 | XAAD7 | External A CH A/D Data 7 |
| 38 | XAAD8 | External A CH A/D Data 8 |
| 14 | XAAD9 | External A CH A/D Data 9 |
| 39 | XAAD10 | External A CH A/D Data 10 |
| 15 | XAAD11 | External A CH A/D Data 11 |
| 40 | XAAD12 | External A CH A/D Data 12 |
| 16 | XAAD13 | External A CH A/D Data 13 |
| 41 | XAAD14 | External A CH A/D Data 14 |
| 17 | XAAD15 | External A CH A/D Data 15 |
| 42 | $\overline{\text{XINT AD EN}}$ | External A/D Enable |
| 18 | PEOC | Pseudo End of Conversion |
| 43 | I/R | Imaginary/Real Point |
| 19 | AEOC | A Channel End of Conversion |
| 44 | $\overline{\text{EXT CONV COMP}}$ | External Conversion Complete |
| 50 | GRD-4 | |

NOTE: All signals are TTL level. The true state is high, unless the signal name is barred.

4. Control Interface, J114

| Pin | Mnemonic | Comments |
|---|---|---|
| 59 | DATA ACC | Data Accept |
| 28 | BLK SYNC PULSE | Block Synchronization Pulse |
| 60 | INPUT PULSE | Input Control Data Strobe Pulse |
| 29 | DISP ADV | Display Advance |
| 61 | HOLD | External Hold |
| 30 | ARM | External Arm |
| 62 | SYS RESET | System Reset |
| 63 | START | External Start |
| 32 | STOP | External Stop |
| 64 | CONT | External Continue |
| 33 | PLOT | External Plot |
| 2 | PLOT SET-UP | External Plot Set-up |
| 34 | AUX | External Aux |
| 3 | CRT ONLY | External CRT Only |
| 35 | | External Control Data 6 |
| 4 | DISPLAY MEMORY | External Display Memory Store |
| 38 | SPARE | |
| 7 | SPARE | |

NOTE: All signals are TTL level. The asserted state is A TTL high, unless the signal name is barred, in which case, the asserted state is a TTL low.

## 19.5 Appendix C

### C. ASCII Character Set

ASCII CHARACTER SET (7-BIT CODE)

| MS CHAR / LS CHAR | 0 000 | 1 001 | 2 010 | 3 011 | 4 100 | 5 101 | 6 110 | 7 111 |
|---|---|---|---|---|---|---|---|---|
| 0 0000 | NUL | DLE | SP | 0 | @ | P | ' | p |
| 1 0001 | SOH | DC1 | 1 | 1 | A | Q | a | q |
| 2 0010 | STX | DC2 | " | 2 | B | R | b | r |
| 3 0011 | ETX | DC3 | # | 3 | C | S | c | s |
| 4 0100 | EOT | DC4 | $ | 4 | D | T | d | t |
| 5 0101 | ENQ | NAK | % | 5 | E | U | e | u |
| 6 0110 | ACK | SYN | & | 6 | F | V | f | v |
| 7 0111 | BEL | ETB | ' | 7 | G | W | g | w |
| 8 1000 | BS | CAN | ( | 8 | H | X | h | x |
| 9 1001 | HT | EM | ) | 9 | I | Y | i | y |

The characters in Columns 0 and 1 can be generated on most terminals by holding the CNTRL key and depressing the corresponding character in Columns 4 and 5, respectively. Example BEL = CNTRL/G. DC1 = CNTRL/Q.

## ASCII CHARACTER SET (7-BIT CODE)

| MS CHAR / LS CHAR | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | 000 | 001 | 010 | 011 | 100 | 101 | 110 | 111 |
| A 1010 | LF | SUB | * | : | J | Z | j | z |
| B 1011 | VT | ESC | + | ; | K | [ | k | { |
| C 1100 | FF | FS | ' | < | L | \ | l | : |
| D 1101 | CR | GS | - | = | M | ] | m | } |
| E 1110 | SO | RS | • | > | N | ↑ | n | ~ |
| F 1111 | SI | VS | / | ? | O | ← | o | DEL |

The characters in Columns 0 and 1 can be generated on most terminals by holding the CNTRL key and depressing the corresponding character in Columns 4 and 5, respectively. Example BEL = CNTRL/G. DC1 = CNTRL/Q.

# SECTION 20

# SELF-TEST

## 20.1 Introduction

The programs in the 660B Self-Test are designed to ensure the 660B Dual Channel Spectrum Analyzer is operating properly and to aid in diagnosing problems in the event of a malfunction.

The Self-Test program alters the normal operation of the 660B and uses the CRT and front panel pushbuttons to display and enter information. Tests performed on the 660B include:

1. Memory Test
   - A. Foreground/Background Test on Random Access Memory (RAM)
   - B. Random Data Test on RAM
   - C. Cyclic Redundancy Check (CRC) on all PROMs

2. FFT Test
   - A. Memory Check of FFT Memory
   - B. Test on Operation of Central Processing Unit (CPU)
   - C. CRC on FFT Constant Table
   - D. Test on Operation of FFT Hardware Multiplier

3. Front Panel
   Check Operation of
   Front Panel Pushbuttons

The Self-Test feature also exercises the 660B display, and the RS232 and IEEE488 interfaces.

## 20.2 Self-Test Procedure

When using the Self-Test program, the normal operation of the 660B is altered. The Self-Test Program uses the CRT and Front Panel pushbuttons to display and enter data. To access the Self-Test program, it is necessary to change an internal setting on the 660B Main Memory Board. To change the necessary setting:

1. Power down the 660B.

2. Remove the top cover of the 660B. To remove the top cover, turn the six quarter turn fasteners located on the cover, counterclockwise.

3. Locate the Main Memory board. There are four (five if Option -2D is included) electronic circuit boards located inside the 660B. The Main Memory Board is labelled and is located, if viewed from the front of the unit, on the right hand side. (See Figure 20-1.)

4. On the top of the Main Memory Board is a three position switch. This switch is used to select the Self-Test program. To enter the Self-Test mode, move the switch to the far rear position.

| CAUTION! | THIS SWITCH MUST BE RETURNED TO FORWARD POSITION TO RETURN THE 660B TO NORMAL OPERATION. |
|---|---|

5. Power up the 660B. The 660B will begin running the Self-Test program.

## 20.3 Test Descriptions

From the POWER ON or SYStem ReSeT position, the Self-Test program checks for proper operation of the portion of the RAM needed by the Self-Test program. If the RAM portion proves to be non-operational, the Self-Test program will not run. All front panel light emitting diodes (LED) blink on and off at approximately a 1 second rate to indicate this failure.

After proper operation has been determined, the LEDs in the FUNCTION section of the front panel will blink on and off. The CRT screen will beginning displaying information and data.

The actual information that appears on the 660B CRT screen will appear in italicized characters.

*ITALICIZED CHARACTER*

In examples that follow, user input to the program is indicated by underlined italicized characters.

*USER INPUT UNDERLINED*

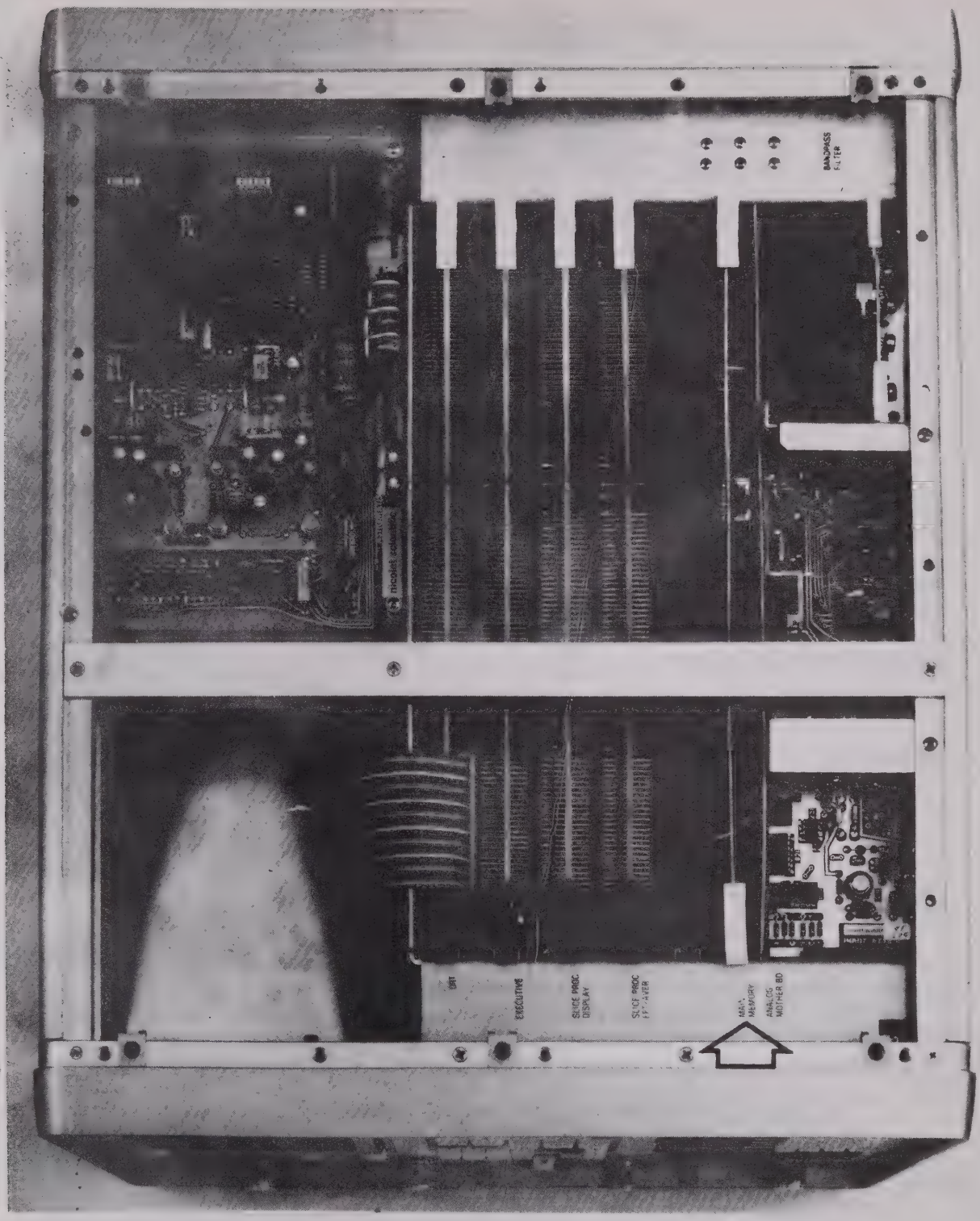



FIGURE 20-1. LOCATION OF 660B MAIN MEMORY BOARD.

The following information will be displayed on the CRT screen of the 660B (Figure 20-2):

1. All 660B Options that are installed in the unit under test, and

2. The Self-Test Menu.

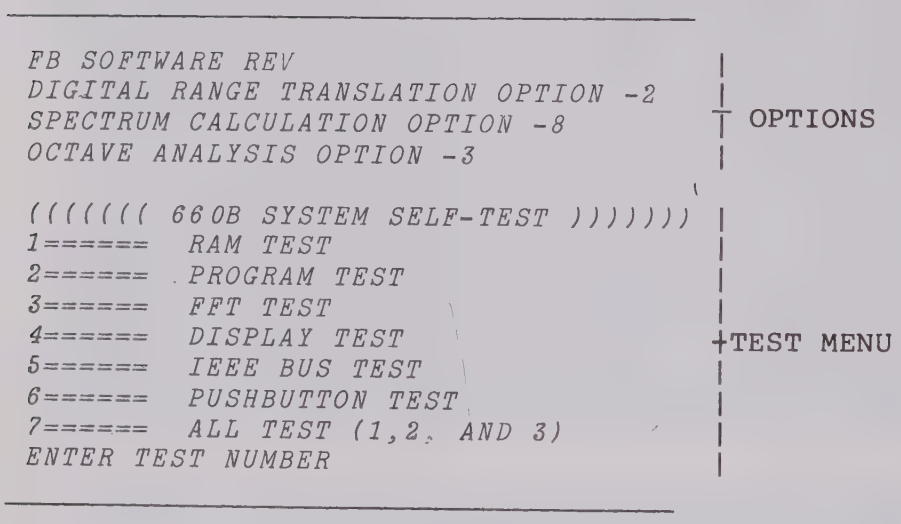



FIGURE 20-2. POWER ON/RESET DISPLAY - LISTING OPTIONS INSTALLED AND TEST MENU.

This information may also be displayed on a RS232 compatible terminal if connected to the RS232 interface on the rear panel.

The program then waits for the user to enter a number for the desired test from the CALCULATION CONTROL group of the 660B. Alternatively, for the RS232 Interface, the correct numeric key is pressed on the terminal. Any exceptions for the RS232 Interface will be noted. Each test is described below.

1. RAM TEST - When the RAM Test (Figure 20-3) is chosen, the CRT displays:

```
<<<RAM TEST>>>
RUN RAM TEST # TIMES (1-9) 1
CHECKING SYSTEM RAM
BLOCK=01   BLOCK=02
```

FIGURE 20-3. RAM TEST DISPLAY.

The program waits for an entry to be made for the number of times the RAM Test should run. In this example, the number of times (1-9) is user chosen to be 1. If 0 is chosen, the portion of the RAM test for the Self-Test program is re-run. If no entry is chosen and the SET/STORE is depressed, the RAM Test will run continuously until an error occurs and may only be exited by use of the ReSeT pushbutton. The current blocks under test are always displayed. (Figure 20-3, Block 01 and 02.)

If no errors are incurred, the CRT displays the message:

```
SYSTEM RAM WORKING
EXECUTED TEST  XXXX TIMES
```

FIGURE 20-4. NO ERRORS IN RAM TESTING.

The program repeats the test the user specified number of times and then returns to the Self-Test Menu.

If an error is incurred, the CRT displays the message:

```
BLOCK=XX XXXXXXXXF[1]
ERROR IN RAM TEST
PRESS ANY KEY TO CONT.
```

[1]F or R will occupy this position indicating a foreground/background (F) or a random data error (R).

FIGURE 20-5. ERROR MESSAGE IN RAM TESTING.

The program will stop executing. The error message should be noted. Press any key to continue the testing.

2. PROGRAM TEST - When the Program Test is chosen (Figure 20-6), the CRT screen will display:

```
<<<PROM TEST>>>
RUN PROGRAM TEST # (1-9) 1
TEST MEMORY
FIXED MEMORY
OVERLAY # 00
OVERLAY # 11
OVERLAY # 22
OVERLAY # 33
```

FIGURE 20-6. PROGRAM TEST.

The program waits for an entry to be made for the number of times the Program Test should run. In this example, the number of times (1-9) is user chosen to be 1. If no entry is chosen and the SET/STORE is depressed, the Program Test will run continuously until an error occurs and may only be exited by use of the ReSeT pushbutton. If 0 is chosen, a different Program Test will run (See "0" Program Test).

The OVERLAY is the block of memory under test. The positions of the PROM errors on the Memory Board are indicated by the letters and numbers following the memory block.

If all of the PROMS are working, the CRT will display:

```
ALL PROMS WORKING
EXECUTED TEST XXXX TIMES
```

FIGURE 20-7. NO ERRORS IN PROM TESTING.

The program repeats the test the user specified number of times and then returns to the Self-Test Menu.

If an error in the Program Test is incurred, the CRT displays the message:

```
SYSTEM FIX XX

ERROR IN PROM TEST
PRESS ANY KEY TO CONT
```

FIGURE 20-8. ERROR MESSAGE IN PROM TESTING.

The program will stop executing. The error message should be noted. Press any key to continue the testing.

"0" Program Test - If a 0 (zero) is entered in response to the initial RUN TEST # TIMES question the CRT will display the alternate program:

```
ENTER BLOCK WANTED
0-OVERLAY #0
1-OVERLAY #1
2-OVERLAY #2
3-OVERLAY #3
4-TEST FIXED
5-SYSTEM FIXED
6-ALL
```

FIGURE 20-9. "0" PROGRAM TEST.

The program then waits for the block number to be entered. When a block is entered, the program will calculate the CRC value for each PROM in that block and display the values. The following format represents a selection of "6" all PROMs.

```
  A2    A3    A4    A5    A6    A7    A8    A9
A93D  1F80  E069  7F35  0C0E  0000  FFB3  1A48
  B2    B3    B4    B5    B6    B7    B8    B9
B949  6E20  25B4  529A  6822  E9A9  D099  F404
  F2    F3    F4    F5    F6    F7    F8    F9
AF45  C0B2  3E61  DF9C  1A73  86A7  70B2  78C6
  E2    E3    E4    E5    E6    E7    E8    E9
F73F  A070  804E  BFB2  4DAE  FA3E  0827  4A42
  D2    D3    D4    D5    D6    D7    D7    D9
A938  5A72  FB87  B892  BFC8  C395  0000  A277
  C2    C3    C4    C5    C6    C7    C8    C9
0000  0000  0000  0000  0000  0000  0000  0000
PRESS ANY KEY TO CONTINUE TEST
```

FIGURE 20-10. CRC VALUE AND PROM LOCATION.

The first line contains the locations of the PROMs on the Main Memory Board. The next line is the CRC value of each prom. This test is for internal NSC use only.

3. FFT TEST - When the FFT Test is chosen, the CRT will display:

```
<<<FFT TEST>>>
RUN TEST # TIMES (1-9) 1
```

FIGURE 20-11. FFT TEST.

The program waits for an entry to be made for the number of times the Program Test should run. In this example, the number of times (1-9) is user chosen to be 1. If no entry is chosen and the SET/STORE is depressed, the test will run continuously until an error occurs and may only be exited by use of the ReSeT pushbutton. If "0" is chosen, a different FFT test will run (See "0" FFT Test).

The FFT Test will display the following information when running:

```
<<<FFT TEST>>>
RUN TEST # TIMES (1-9) 1
FFT CPU WORKING
CONSTANTS
SCRATCH PAD TEST ALL MEMORY WORKING
MULTIPLIER TEST MULTIPLIER WORKING
SLICE MEMORY DATA TEST ADDRESS TEST
ALL MEMORY WORKING
EXECUTED TEST XXXX TIMES
```

FIGURE 20-12. FFT TEST DISPLAY.

If no errors are incurred, the program will repeat the user specified number of times and return to the Self-Test Menu.

There are five different types of errors that may occur with this test and these errors are displayed on the CRT screen.

```
FFT CPU NOT WORKING FAIL TEST #XX
PRESS ANY KEY TO CONT

CONSTANT XX, XX
SCRATCH PAD TEST ERROR IN MEMORY #XX
PRESS ANY KEY TO CONT

MULTIPLIER ERROR = XXXX x XXXX
RESULT = XXXXXXXX
PRESS ANY KEY TO CONT

SLICE MEMORY DATA TEST

ERROR BITS = XXXXXXXX XXXXXXXX
PRESS ANY KEY TO CONT
```

FIGURE 20-13. ERROR MESSAGES FOR FFT TEST.

The program will stop executing. The error message should be noted. Press any key to continue the testing.

"0" FFT Test - If a 0 (zero) is entered in response to the initial RUN TEST # TIMES question the CRT will display the alternate FFT Test program:

```
<<<RUN ONE FFT TEST>>>
ENTER BLOCK WANTED
1-CPU TEST
2-CONSTANT ROM
3-SCRATCH PAD TEST
4-MULT TEST
5-SLICE MEMORY TEST
ENTER TEST NUMBER 3

SCRATCH PAD TEST
RUN TEST # TIMES (1-9) 1
SCRATCH PAD TEST ALL MEMORY WORKING
EXECUTED TEST 0001 TIMES
```

FIGURE 20-14. "0" FFT TEST.

This mode of operation is used to loop on one particular test for diagnostic information. This test is for internal NSC use only.

4. DISPLAY TEST - When the Display Test is chosen, the CRT will display:

```
DISPLAY ADJUSTMENT
PRESS ANY KEY FOR NEXT TEST
```

FIGURE 20-15. DISPLAY TEST.

The normal 660B display would be contained within the box. This pattern should be used to focus and adjust the 660B display.

Pressing any key on the front will display the available alphanumeric characters.

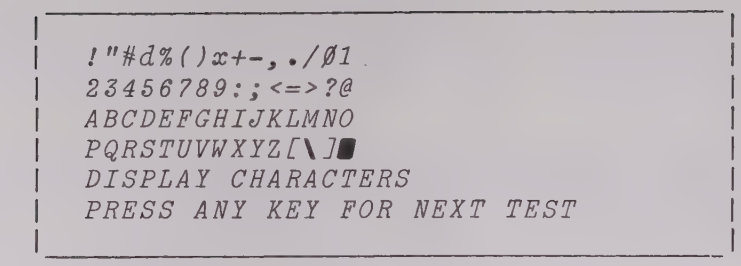



FIGURE 20-16. ALPHANUMERIC CHARACTERS.

Pressing any key will display data in the form of an increasing ramp from left to right.

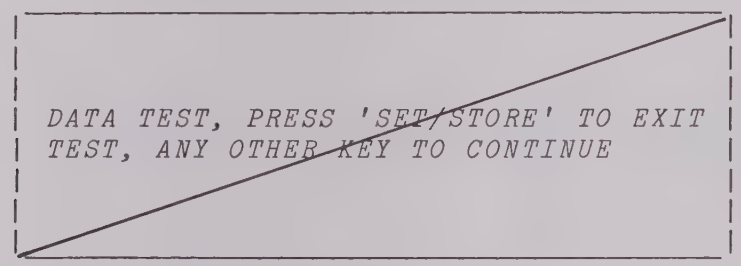



FIGURE 20-17. CORRECT DISPLAY.

If this data is correct, press SET/STORE to exit the Display Test. If the display is not correct or additional testing is desired, pressing any other key will display a horizontal line across the display.

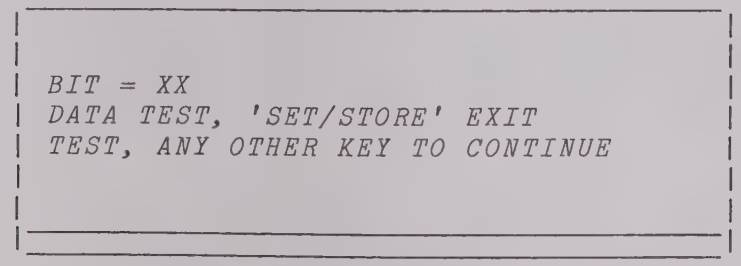



FIGURE 20-18. FURTHER DISPLAY TESTING.

Each time a key is pressed, the diagonal line will move toward the top of the display one step at a time. Twelve steps are available. Each step tests one bit of the D/A converter of the display. SET/STORE may be pressed at any time to exit the test.

5. IEEE488 TEST - When the IEEE488 Test is chosen the CRT displays:

```
<<<IEEE488 BUS TEST>>>
ENTER '0' FOR TEST  '1' FOR SINGLE STEP  0
```

FIGURE 20-19. IEEE488 TEST.

The program waits for a 0 or 1 to be entered. The 0 Test should be chosen by the user. The 1 Test is for NSC internal use only. When the 0 Test is chosen, the program checks internal operation of the 660B IEEE488 bus. The CRT then displays:

```
   488 INPUT DATA TEST
1-CONNECT A CONTROLLER TO THE 488 BUS
2-WRITE A '+U' TO ADDRESS ON GBIP
3-PRESS ANY KEY
```

FIGURE 20-20. IEEE488 INPUT DATA TEST.

A typical command to enter this information using a Hewlett Packard Model HP9825A calculator would be:

```
wtb707,"+U"
```

FIGURE 20-21. INPUT TEST USING HP9825A CALCULATOR.

When any key is pressed on the 660B, the program checks the information transmitted over the bus. If information is incorrect, an error message will be displayed (see Error Listing, 20.4.

After passing the input test, the CRT will display:

```
   488 OUTPUT DATA TEST
1-CONNECT A CONTROLLER TO THE 488 BUS
2-REMOTE ENABLE ADDRESS 7
3-READ 660 DATA
4-PRESS ANY KEY
```

FIGURE 20-22. IEEE488 OUTPUT DATA TEST.

In the output test the 660B transmits a character to the controller and the Self-Test verifies that the 660B is set up correctly for this operation. The user is required to execute the read command and then press any key of the 660B to transmit the data. The data that is transmitted is the ASCII value of the letter 'A'. A typical command using an HP9825A calculator would be:

```
rem707;rdb(707)->X: dspchar(X)
```

FIGURE 20-23. OUTPUT TEST USING HP9825A.

The Self-Test Program outputs an error message if the 660B is not set up correctly to transmit data. The user should also verify that the character received is the letter A.

After passing the IEEE488 Output Test, the CRT will display:

```
   EOI LINE TEST
1-SET THE EOI LINE TRUE
2-PRESS ANY KEY
```

FIGURE 20-24. EOI LINE TEST.

The user should set the EOI Line on the IEEE488 interface true, and then press any key to continue. The Self-Test program will read the EOI Line and verify that it is set. If the line is not set an error message will occur:

```
EOI LINE ERROR
```

FIGURE 20-25. EOI LINE ERROR.

A typical command using the HP9825A to set the EOI Line would be:

```
wti0,7;cmd7,char(213);cmd7,char(167);wti7,146;wti4,4
```

FIGURE 20-26. EOI LINE SET USING THE HP9825A.

After reading the EOI Line, the Self-Test program will set the SRQ Line and display the following message:

```
   THE SRQ LINE IS SET TRUE
1= READ SRQ LINE
2= PRESS ANY KEY
```

FIGURE 20-27. SRQ LINE SET.

The user should read the SRQ Line, verify that it is set and then press any key to exit the IEEE488 Bus Test.

When a 1 is entered, the CRT will display:

```
<<<IEEE488 BUS TEST>>>
ENTER '0' FOR TEST  '1' FOR SINGLE STEP

488 SINGLE STEP TEST
ENTER 488 DATA AND PRESS ANY BUTTON
TO VIEW REGISTERS
PRESS SET/STORE ONLY TO EXIT TEST

INTERRUPT STATUS REGISTER          10
COMMAND STATUS REGISTER            10
ADDRESS STATUS REGISTER            00
AUXILIARY COMMAND REGISTER         70
ADDRESS SWITCH REGISTER            FF
SERIAL POLL REGISTER               00
COMMAND PASS-THROUGH REGISTER      00
DATA IN REGISTER                   00
```

FIGURE 20-28. 488 SINGLE STEP TEST.

If an error occurs in the 488 Bus Test, the Self-Test program will output an error message in the form:

```
ERROR SYSTEM NOT SET TO LISTENER
ADDRESS STATUS REGISTER
BAD DATA=XX   GOOD DATA=XX
PRESS ANY KEY FOR NEXT TEST
```

FIGURE 20-29. 488 BUS TEST ERROR MESSAGE.

6. FRONT PANEL PUSHBUTTON TEST - If the Front Panel Test is chosen, the CRT will display:

```
<<<PUSHBUTTON TEST>>>
PRESS KEY TO READ NAME
PRESS SET/STORE ONLY TO EXIT TEST

PUSHBUTTON ---TIME
```

FIGURE 20-30. PUSHBUTTON TEST.

Any key on the front panel can be depressed and the CRT will respond with the name of the key. The CRT responds with a maximum of four characters to identify the depressed key. If the CRT fails to respond with a key name or displays an incorrect name, this is a test error and should be noted by the user. In this example, the INPUT TIME pushbutton was depressed and the CRT responded correctly with TIME for the name of the pushbutton.

7. ALL TEST (1,2,3) - When ALL TEST is chosen the CRT will display:

```
<<<ALL TEST 1,2,3>>>
RUN TESTS # TIMES (1-9)
```

FIGURE 20-31. ALL TEST.

The program waits for the RUN TEST # TIME question to be answered. If the SET/STORE is depressed, the test will run continuously until an error is incurred. ReSeT must be used to exit the test in this mode.

The All Test option permits Tests 1, 2, and 3 to be run as one test. The RAM Test is executed first, then the Program Test, followed by the FFT Test.

## 20.4 SELF-TEST ERRORS

1. LEDs

   A. All Front Panel LEDs Flashing - Error in the 660B Self-Test RAM (0000-03FF$_{HEX}$). (Locations E11, F11, of Main Memory RAM.)

      The LEDs in the MODE section plus remote control LED indicate error bits.

      BIT 0 - REMOTE
      BIT 1 - PROB
      BIT 2 - 1K DUAL
      BIT 3 - CORR
      BIT 4 - SIG ENH
      BIT 5 - CHA 2K
      BIT 6 - TEXT
      BIT 7 - OCT OR OPT-5

   B. LEDs in the FORMAT section ON indicate a slice board start or stop error*1*,*2*.

      REAL LED ON - Slice did not start correctly which was indicated by an incorrect status.

      MAG LED ON - Slice did not start which was indicated by no start status.

      R/I LED ON - Slice did not stop correctly, indicated by an incorrect stop status.

      $\phi$/MAG LED ON - Slice did not stop, indicated by no stop status.

      *1*A message will be transmitted over the RS232 Interface indicating which board is in error. (See Error Messages.)
      *2*If the problem is the FFT board, the Self-Test program will stop.

2. SYSTEM ERROR MESSAGES

The following is a list of errors that may occur during any of the tests and are not directly related to the execution of any particular test.

*TIME OUT ERROR IN FFT PROGRAM* -This error indicates that the FFT Board took too long to run in the Self-Test Program.

*ERROR IN SELF-TEST STATUS* - This error indicates that the FFT will not run the Self-Test program.

*NO BUTTON SHOULD BE PRESSED AT THIS TIME, THESE ARE* - This error indicates that one or all of the following front panel pushbuttons are stuck in the on position or are depressed.

*FFT GAVE BAD STATUS FOR TRANSFER* or *DISPLAY GAVE BAD STATUS FOR TRANSFER* - This error indicates that the slice gave the incorrect status for a data transfer.

*PHANTOM INTERRUPT FOR IRQ #X* - This error indicates that an incorrect IRQ# has been received.

*FFT GAVE BAD STATUS ON START* or *DISPLAY GAVE BAD STATUS ON START* - This error indicates that the slice board gave the incorrect status to start the program.

*FFT DID NOT START* OR *DISPLAY DID NOT START* - This error indicates that the slice board did not start the program.

*DISPLAY GAVE BAD STATUS ON STOP* - This error indicates that the display board did not stop the program correctly.

*DISPLAY DID NOT STOP* - This error indicates that the display board did not stop the program.

# SECTION 21

## OPTIONS

This section of the instruction manual contains instructions for operating options purchased for the 660 Dual Channel Analyzer.

Current available options and instructions for those options included in this section are a follows:

| | |
|---|---|
| Option -2D | Digital Expander |
| Option -3 | Octave |
| Option -7 | Excitation Source Option |
| Option -8 | Spectrum Calculation |

# Option -2D Digital Expander

The Digital Expander (Option -2D) for the 660B Dual-Channel Analyzer provides increased frequency resolution. Seven different expansion ratios allow windows to be used which range in width from .64 Hz (5 Hz, expansion ratio 8) to 12,500 Hz (100 KHz, expansion ratio 8). The basic resolution of the 660B, 400 points in dual-channel operation and 800 points in single-channel operation, is retained.

The center frequency of the expansion window can be set as resolutely as 1/100,000 of the selected range, for example, .00005 Hz in the 5 Hz range. The maximum resolution in single-channel operation is 1/800 of the selected window width, for example, 8 mHz for a .64 Hz window.

The anti-aliasing filters of the 660B remain operative when the Digital Expander is used. Since the same resolution may be available with different low-pass filters in use, an optimum choice can be made.

Most 660B features are not effected by expansion. All functions in the CALCULATION CONTROL section are still available, including interchannel delays, differentiation, and integration. All averaging modes may still be used, and the data can be displayed in any format desired.

1. XPND

The XPND pushbutton in the CALCULATION CONTROL section is used to activate the Digital Expander. The desired center frequency is entered in the current horizontal units of measure (Hz, CPM, ORDERS), followed by SET XPND. This sequence activates the Digital Expander and sets the center frequency. The current cursor location may be used as the expansion window center frequency by entering the key sequence: CLEAR SET XPND.

When the Digital Expander is enabled, the upper (right) and lower (left) frequency extremes in the current expansion window are annotated in the upper-left of the screen. See Figure D-1. This annotation can be recalled at any time by the key sequence: RECALL XPND, providing the Digital Expander is on.

If the Digital Expander is not on, this sequence will activate the Digital Expander and set the center frequency to that used in the last expansion. The upper and lower frequencies are annotated as in Figure D-1.

FIGURE D-1

2. CLEAR XPND

The key sequence: CLEAR XPND causes the Digital Expander to be turned off, annotation made in the entry field, and to return to a baseband display. Depressing a MODE pushbutton, or changing the FREQUENCY RANGE switch, will also cause the Digital Expander to be turned off. The center frequency is retained internally, and pressing RECALL XPND will restore the same window at the same frequency assuming it is valid in the current mode and range.

The ratio of the center frequency to the selected frequency range is stored within the 660B. Therefore, if the frequency range is changed, the new center frequency will be the same proportion of the frequency range as the previous.

3. XPND WDTH

The XPND WDTH pushbutton is used to modify the window width and expansion ratio. The window width and expansion ratio are related: FREQUENCY RANGE = (Expansion Ratio)(Window Width). The wake up state is an expansion ratio of 8. The expansion ratio is used internally and remains constant unless specifically altered by the operation. The valid combinations of frequency range and expansion ratio are given in Table D-1.

When the Digital Expander is activated through use of the XPND pushbutton, the actual expansion ratio is displayed in the lower right-hand corner of the screen. Except in the 100 K range, the number will be 2.4% smaller than the entries in Table D-1. The table gives nominal values.

TABLE D-1

FREQUENCY RANGES AND EXPANSION RATIOS

| FREQUENCY RANGE (filter cutoff Hz) | NOMINAL RESOLUTION OF SETTING | EXPANSION RATIOS AND WINDOW WIDTHS (HZ) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | X8* | X16 | X32 | X64 | X128 | X256 | X512 |
| 100 K | 1.0 | 12500 | 6250 | 3125 | 1562 | 781.2 | 390.6 | 195.3 |
| 50 K | 0.5 | 6400 | 3200 | 1600 | 800 | 400 | 200 | 100 |
| 20 K | 0.2 | 2560 | 1280 | 640 | 320 | 160 | 80 | 40 |
| 10 K | 0.1 | 1280 | 640 | 320 | 160 | 80 | 40 | 20 |
| 5 K | 0.05 | 640 | 320 | 160 | 80 | 40 | 20 | 10 |
| 2 K | 0.02 | 256 | 128 | 64 | 32 | 16 | 8 | 4 |
| 1 K | 0.01 | 128 | 64 | 32 | 16 | 8 | 4 | 2 |
| 500 | 0.005 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| 200 | 0.002 | 25.6 | 12.8 | 6.4 | 3.2 | 1.6 | 0.8 | N/A |
| 100 | 0.001 | 12.8 | 6.4 | 3.2 | 1.6 | 0.8 | N/A | N/A |
| 50 | 0.0005 | 6.4 | 3.2 | 1.6 | 0.8 | N/A | N/A | N/A |
| 20 | 0.0002 | 2.56 | 1.28 | .64 | N/A | N/A | N/A | N/A |
| 10 | 0.0001 | 1.28 | 0.64 | N/A | N/A | N/A | N/A | N/A |
| 5 | 0.00005 | 0.64 | N/A | N/A | N/A | N/A | N/A | N/A |

*Initialized condition on power turn or reset.

The window width may be set explicitly in the current units of measure (Hz, CPM, ORDERS) by pressing the sequence: (number) SET XPND WDTH. If the width requested is not an exact width from Table D-1, then the next larger size window for that frequency range will be selected. If, however, the window requested is larger than the largest valid window, the largest valid window will be selected. The window width selected will be annotated in the upper left-hand corner of the screen, as in Figure D-2.

Alternatively, a decimation ratio can be set by the key sequence: ___ (number) SET XPND WDTH. If the user attempts to set a number which is not one of the seven listed in Table D-1, the next smaller ratio will be selected. The sequence: RECALL XPND WDTH will cause the current window width to be annotated on the screen, as in Figure D-2. The sequence: CLEAR XPND WDTH will cause the wake up state, expansion ratio of 8, to be selected.

None of the key sequences involving the XPND WDTH push-button cause the Digital Expander to be activated or deactivated. If an invalid width is requested, no change will result. In addition, all of the sequences involving the XPND WDTH pushbutton can be executed whether the Digital Expander is on or off.

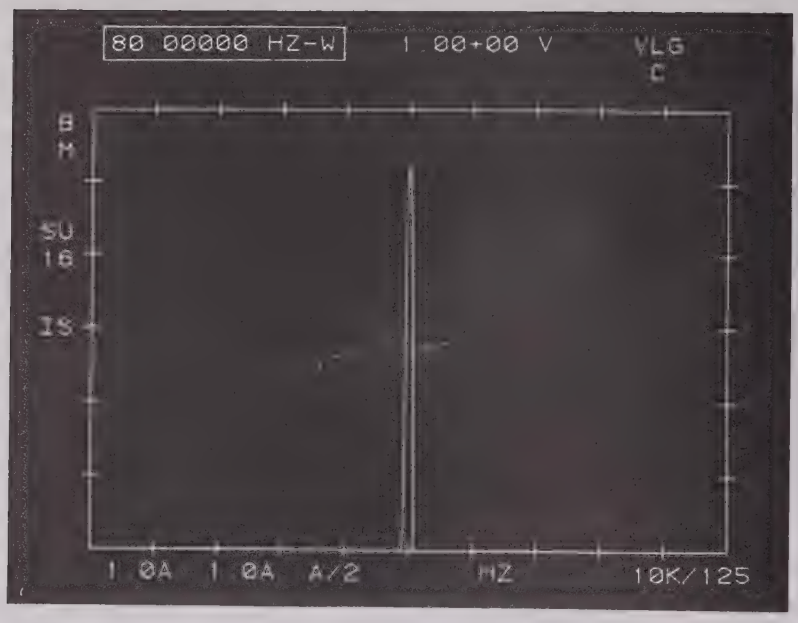



FIGURE D-2

4. Analysis Length

Due to the high resolution of the Digital Expander, the analysis may take appreciable amounts of time, especially in the lower frequency ranges or higher expansion ratios. The exact time may be found by multiplying the TIME WINDOW, located on the front panel of the 660B, by the expansion ratio.

5. Interpretation of Expansion Parameters Stored in Data Buffer 0 (Reference: Section 19)

The two parameters stored in data buffer 0 which pertain to the Digital Expander are STDCRN (1 byte at offset 38), and STRXR (5 bytes at offset 39). STDCRN stores the code for the expansion ratio currently in use. The expansion ratio can be determined using the contents of STDCRN and the table below. All codes other than 1 through 7 are invalid. On power up, this byte is set to 1.

| STDCRN | Expansion Ratio in FREQ RANGE 5-50 kHZ | Expansion Ratio in 100 kHz Range |
|---|---|---|
| 1 | 7.8125 | 8 |
| 2 | 15.625 | 16 |
| 3 | 31.25 | 32 |
| 4 | 62.5 | 64 |
| 5 | 125.0 | 128 |
| 6 | 250.0 | 256 |
| 7 | 500.0 | 512 |

STRXR contains the ratio of the current or most recent center frequency to the maximum frequency in that range. The ratio is stored internally with scale factors applied. The following formula may be used to calculate the center frequency from the contents of STRXR.

$$\text{center frequency} = (\text{STRXR})(10^{-5})(\text{frequency range})$$

STFRRD (1 byte at offset 22) can be used to determine whether or not the Digital Expander is currently on or off. If bits 1 and 7 are at 1, the Digital Expander is on.

6. Error Codes

The following errors may result from the use of XPND or XPND WDTH pushbuttons. Errors appear in inverted type in the upper-left of the display screen. The action which caused the error does not alter any system parameters.

| Error | Description |
|---|---|
| NO EXPANDER | Attempt to SET, RECALL, or CLEAR expansion in a unit which does not contain Digital Expander Option -2D. |
| TURN ON CURSOR | Attempt to set location of window using cursor when cursor is off. |
| >MAX FREQ | Attempt to SET or RECALL a window beyond the maximum frequency of selected range. |
| <MIN FREQ | Attempt to SET, RECALL, or CLEAR center frequency or width that would cause the center to be less than 1/2 the expanded band. |
| EXIT COMP | Attempt to set window on active data in COMP which does not match stored data. |
| EXIT EQL | Attempt to set window on active data in EQL which does not match stored data. |
| FREQ MISMATCH | Attempt to set center of window on active data in COMP or EQL which does not match stored data. |
| STORED DATA | Attempt to change expansion state of stored data. |
| VIEW FREQUENCY | Attempt to SET or RECALL expansion in time domain or CORR mode. |

## O-1. OVERVIEW

OCTave is a MODE modifier available for use with the Dual Channel 1K FFT or Single Channel 2K FFT modes. One-third or 1/1 octave analysis may be performed over ten octaves on one channel (CHA 2K) or two channels (DUAL 1K). Additionally, A-weighting may be applied in processing 1/3 or 1/1-octaves. Once an FFT mode has been selected then the OCTave pushbutton may be depressed.

The octave process has two modes of operation, the first is known as "2 Pass" and will produce a full spectrum of data, thirty 1/3 octave bands and ten 1/1 octave bands. The second is known as "1 Pass" and will produce a half spectrum of data, fifteen 1/3 octave bands and five 1/1 octave bands. The difference between these modes is processing speed with the half spectrum of data, or 1 Pass, operation requiring much less time.

Selection of 1/1 OCTave, 1 or 2 Pass; or 1/3 OCTave, 1 or 2 Pass; will be done through the DEFine AUX codes with 1/3 OCTave, 1 Pass defined as the default. A-Weighting is also available through the DEFine AUX codes.

A special feature of the 660B Octave Option is complex octave magnitudes. 1/1 or 1/3 Octave data may be processed in a dual channel mode to produce 1/1 or 1/3 octave filtered cross spectrum data. These outputs have the same physical significance as the narrow band counterparts with the benefit of synthesized octave display.

## O-2. 1/3, 1/1 OCTAVE 200 SERIES OF DEFINE AUX

To select 1/1 or 1/3 OCTave, the 200 series DEFine AUX codes are used. These codes are entered by using the CALCULATION CONTROL group of the Analyzer or the RS232 or IEEE-488 interfaces.

Note, it is not necessary to be in the OCTave MODE to enter these codes. However, to display the 1/1 or 1/3 octave data the OCTave pushbutton must be depressed.

The 200 series DEFine AUX codes are defined as:

1/3 OCTave:[1]

200 DEFine AUX - Also the POWER-ON default code. A 1 Pass 1/3 octave spectrum is illustrated in Figure O-1. The entry field (upper left hand corner) depicts the proper DEFine AUX code.

204 DEFine AUX - A 1 Pass 1/3 octave spectrum with A-weighting is illustrated in Figure O-2. The upper right hand corner shows CA indicating A-weighting is enabled.

201 DEFine AUX - A 2 Pass 1/3 octave spectrum is illustrated in Figure O-3.

205 DEFine AUX - A 2 Pass 1/3 octave spectrum with A-weighting is illustrated in Figure O-4. The CA indicates A-weighting is enabled.

1/1 OCTave:[1]

202 DEFine AUX - A 1 Pass 1/1 OCTave spectrum is illustrated in Figure O-5.

206 DEFine AUX - A 1 Pass 1/1 OCTave spectrum with A-weighting is illustrated in Figure O-6. The CA indicates A-weighting is enabled.

203 DEFine AUX - A 2 Pass 1/1 octave is illustrated in Figure O-7.

207 DEFine AUX - A 2 Pass 1/1 octave with A-weighting is illustrated in Figure O-8. The CA indicates A-weighting is enabled.

[1]Note: The 1/3 and 1/1 octave plots listed as examples for the DEFine AUX codes were derived from broad band and narrow band frequency spectra.

## O-3. OCTAVE COMPUTATION

OCTave will be computed on instant spectra or averaged spectrum data that is resident in the averager buffers. Averaged narrow band spectra will be automatically converted to 1/1 or 1/3 octave filtered data upon entering the OCTave MODE. The following is a list of cautions.

1. If a 2 Pass octave is desired, then the averaged data must be taken in the OCTave MODE with the DEFine AUX code for the 2 Pass operation set.

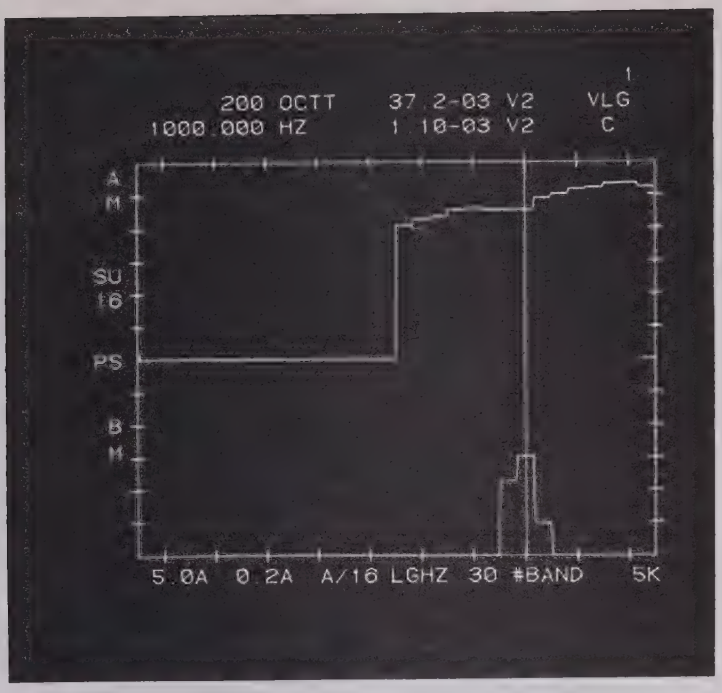



FIGURE O-1

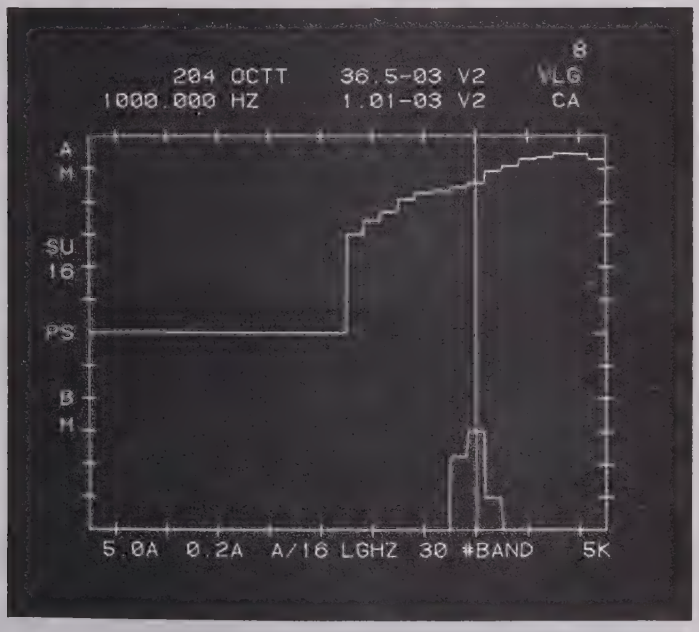



FIGURE O-2

FIGURE O-3

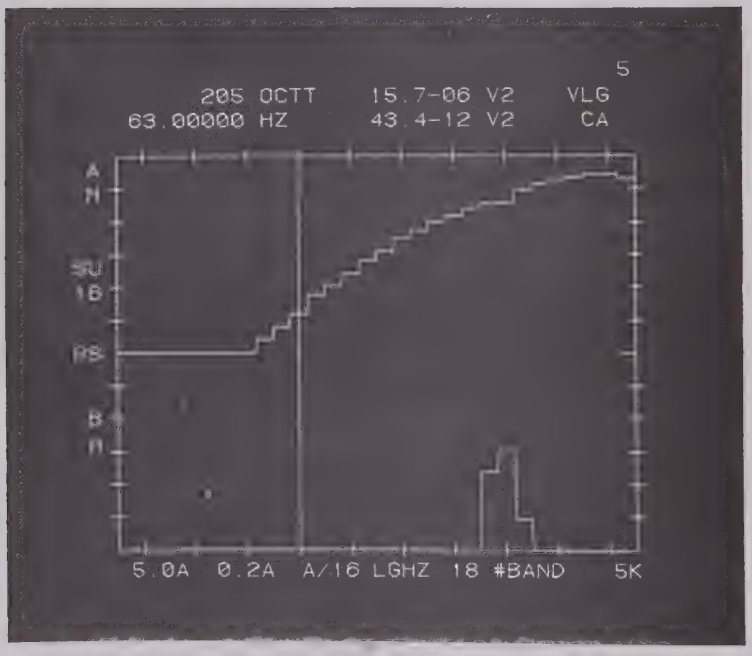



FIGURE O-4

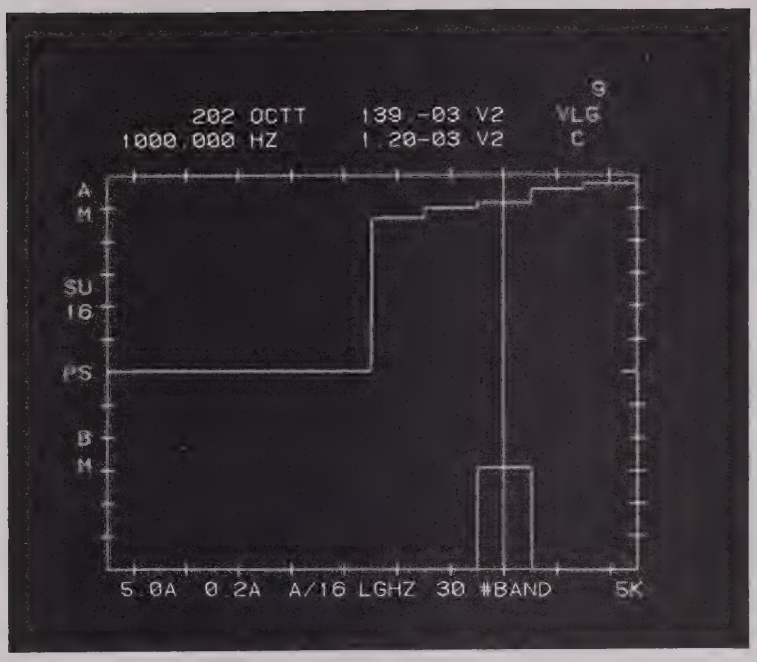



FIGURE O-5

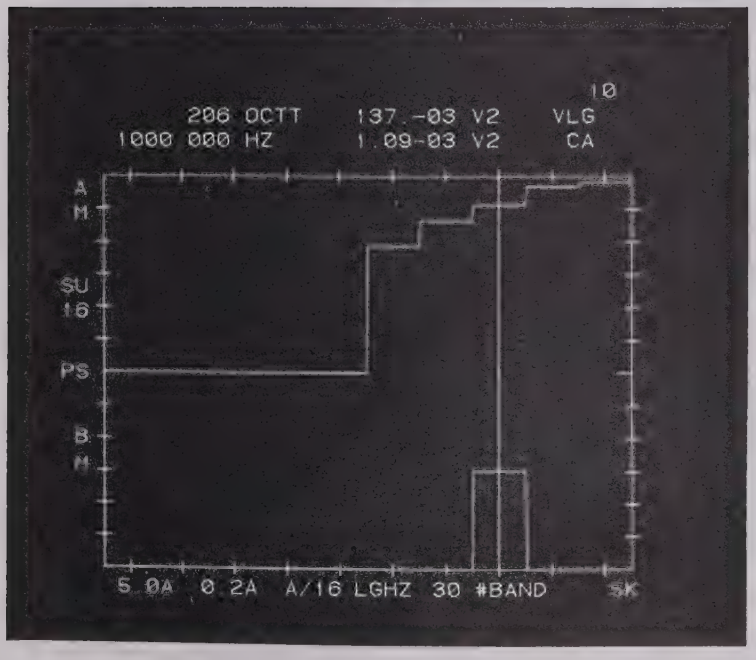



FIGURE O-6

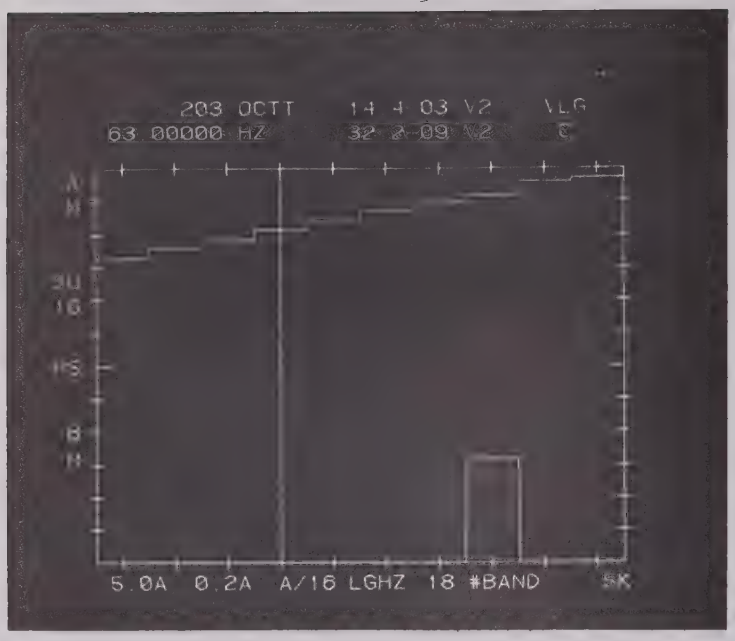



FIGURE O-7

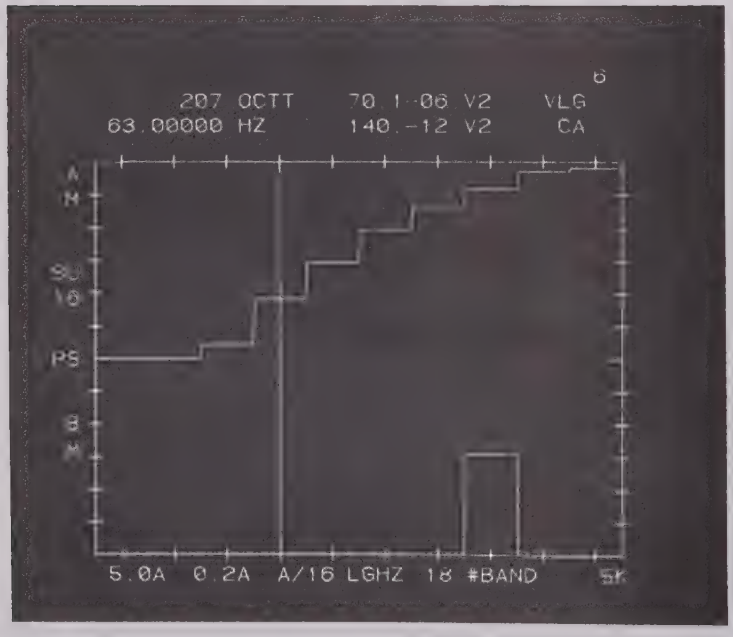



FIGURE O-8

2. If translated data is in the averager buffers; the OCTave results will NOT be correct.

3. Octave scaling assumes that Hanning weighting is applied to narrow band data.

When in 2 Pass operation, with the OCTave MODE enabled, the analog filters are automatically switched. When the system is sampling data for the first pass, the analog filters are set to the frequency range selected by the FREQUENCY RANGE switch.

When a full buffer of data has been taken, the analog filters are automatically switched to a frequency range that is four (4) ranges lower. This cycle is always in operation while in 2 Pass operation even if the averager is not running.

Frequency range selection is limited to between 500 Hz to 100 kHz.[1] If a frequency range below 500 Hz is selected the range will be forced to 500 Hz and the error message USE 500 HZ will appear.

## O-4. OCTAVE MODE AVERAGING RESTRICTIONS

When in the OCTave MODE, the following types of averaging restrictions exist:

1. 1 Pass - 1/1 OCTave - No Restrictions
   1 Pass - 1/3 OCTave - No Restrictions
2. 2 Pass - 1/1 OCTave - PEAK, SWEEP, TRAN are not allowed.
   2 Pass - 1/3 OCTave - PEAK, SWEEP, TRAN are not allowed.

## O-5. AVAILABLE FUNCTIONS

When in the OCTave MODE, the following functions are available:

1. INPUT TIME - 1K or 2K MODE
2. INSTANT SPEC - 1K or 2K MODE
3. RMS - 1K or 2K MODE
4. POWER - 1K or 2K MODE
5. TF - 1K MODE ONLY
6. COH - 1K MODE ONLY
7. TM - 1K MODE ONLY
8. COP - 1K MODE ONLY
9. CS - 1K MODE ONLY

## O-6. ANALYZER CONDITIONS

When in the OCTave MODE, the following conditions are true for the 660B Analyzer.

---

[1]When the 100 kHz or 50 kHz frequency range is selected, the highest 1/3 octave filter will not be computed.

1. External Sampling is disabled.
2. Digital Range Translation is disabled.
3. INT/DIF is disabled.
4. RMS 1-2 is disabled.
5. Redundancy is forced to 0%.
6. Magnitude is the only display format. (Overlap is allowed.)
7. Horizontal Display is forced to LOG.
8. Hanning Weighting is forced ON.
9. PSD (per Hz) is always applied to the narrow band data regardless of the octave processing mode.

## O-7. AVERAGER BUFFERS

Buffers 4, 5, 6, and 7 are used for the 1 Pass portion of the octave calculation. 2 Pass is derived from a different set of buffers whose access is limited to internal use by the averager.

Pass 1 is always averaged first. The average N is updated after 2 Pass has been averaged. If the STOP pushbutton is depressed during the collection of 2 Pass data, the averager will stop after the 2 Pass data has been averaged.

## O-8. DISPLAY CHARACTERISTICS

With the OCTave MODE in use, for 1/1 OCTave the display is set to ten octave bands. The five bands to the right of center screen are 1 Pass as can be seen in Figure O-5. The five bands to the left of center screen are 2 Pass as can be seen in Figure O-7.

For 1/3 OCTave the display is set to thirty octave bands. The fifteen bands to the right of center screen are 1 Pass as can be seen in Figure O-1. The fifteen bands to the left of center screen are 2 Pass as can be seen in Figure O-3.

## O-9. CURSOR

### Readout

The cursor is positioned at the center of any octave band. The octave band frequency is displayed in the cursor output field. The band number that corresponds to the octave band frequency is displayed next to the frequency range. For example, in Figure O-1 using the 1/3 OCTave MODE, 1 Pass, 5K RANGE, CURSOR READS 1000.000 Hz, the following would be displayed at the lower left of the graticule:

| | | | |
|---|---|---|---|
| | LGHZ | 30 #BAND | 5K |
| | ↑ | ↑ | ↑ |
| Log horizontal | | Band Number for 1000 HZ | Frequency Range |

Positioning

When the CURSOR MOVE LEFT OR RIGHT joystick is activated, the cursor moves from the center of one band to the center of the next band.

Store and Recall of Cursors

For non-OCTave MODEs the cell number is stored for a cursor location, not the absolute or relative frequency. For OCTave MODEs, the relative band number is stored for a cursor location, not the absolute band number.

For 1/1 OCTave, relative band numbers 1-10 can be stored or recalled. For 1/3 OCTave, relative band numbers 1-30 can be stored or recalled.

The following examples demonstrate storage and recall of the cursor. The examples are based on Figures O-1 and 0-5 where the RANGE is 5K.

Example:

A cursor at cell number 12 is stored in a non-OCTave mode. If this stored cursor is recalled in a 1/1 OCTave mode, then the cursor would now be positioned at band number 6 and an error message will appear: (1>10). For 1/1 OCTave the highest relative band is 10, therefore, the request for band number 12 can not be honored.

If this same cursor was recalled in 1/3 OCTave, then the request would be honored and the cursor would be positioned at band number 12. An error message (1>30) would appear if a number is larger than 30 for 1/3 OCTave is requested. In addition, the cursor would be forced to band 16.

## O-10. DISPLAY BUFFERS

The sources of data for the display when in the OCTave mode are buffers 2 and 3. See Section 19 of this manual on Interfacing. The data in these buffers is the calculated 1/3 or 1/1 octave for the function that is being viewed, scaled by AVERAGE N and by the attenuator settings.

The data in these buffers is formatted in 3-byte floating point. The buffers contain 30 data points where the first point represents data from the second pass (i.e. the lowest frequency octave filter).

In 1/3 OCTave the first 15 points are 2 Pass and the remaining 15 points are 1 Pass.

In 1/1 OCTave the first 5 points are 2 Pass and the next 5 points are 1 Pass.

## O-11. SPECIAL FEATURES

### OCTave and Narrow Band Comparisons

For any valid function in 1/1 or 1/3 OCTave, the OCTave mode may be toggled for comparison between OCTave and 1 Pass narrow band data. Note, that the averager is stopped when turning OCTave on or off.

### Changing DEFine AUX Codes

Different OCTave MODES may be viewed without averaging new data.

A. Changing From a 1 Pass to a 2 Pass System - The second pass will be calculated on whatever data was in the second Pass averager buffers unless INST is being viewed. It is recommended that averaging be initiated to ensure that the data in these buffers is correct.

B. Changing From 2 Pass to a 1 Pass System - The display that contains the 2 Pass portion of the data will be cleared. The 2 Pass averagers remain untouched. Only 1 Pass octave calculations will be done.

### A-Weighting

A weighting does not alter the narrow band data in the averager buffers. A-weighting is only applied to the OCTave display buffers.

### DISPLAY MEMORY Controls

The DISPLAY MEMORY controls (STO D, RCL D, COMP D) may be used to store, recall or compare OCTave data.

### Derived Data Equations

The following list of equations describes how the cross spectrum octave functions are calculated within the analyzer from the narrow band spectrum data.

Definitions:

$I_R$ = Real Part of the Instantaneous Signal from Channel A or Channel B.

$I_i$ = Imaginary Part of the Instantaneous Signal from Channel A or Channel B.

$P_X$ = Power Spectrum from Channel A or Channel B.

CO = Colinear Component of Cross Spectrum.

QUAD = Quadrature Component of Cross Spectrum.

$P_A$ = Power Spectrum of Channel A.

$P_B$ = Power Spectrum of Channel B.

$[\ ]_z$ = Defines the Operation of 1/1 or 1/3 Octave Filtering

Octave Definitions:

1. Octave Instantaneous Spectrum:[1] $[(I_R)^2 + (I_i)^2]_z^{1/2}$

2. Octave RMS Spectrum: $[(P_X)_z]^{1/2}$

3. Octave Power Spectrum: $(P_X)_z$

4. Octave Cross Spectrum Magnitude:[1] $[(CO^2 + QUAD^2)^{1/2}]_z$

5. Octave Transfer Function Magnitude:[1]

$$\frac{[(CO^2 + QUAD^2)^{1/2}]_z}{(P_A)_z}$$

[1]The dynamic range of these functions is limited to 50 dB.

6. Octave Transmissibility:[1]

$$\left|\frac{\overline{(P_B)_z}}{\overline{(P_A)_z}}\right|^{1/2}$$

7. Octave Coherent Output Power:[1]

$$\frac{[(CO^2 + QUAD^2)]_z}{(P_A)_z}$$

8. Octave Coherence:[1]

$$\frac{[(CO^2 + QUAD^2)]_z}{[(P_A)_z] \bullet [(P_B)_z]}$$

---

[1]The dynamic range of these functions is limited to 50 dB.

Examples of cross spectrum OCTave data are listed, the same low pass band data is the source for the 1/1 and 1/3 OCTave computations.

If 1/3 OCTave MODE, 2 Pass Operation, A-Weighted Data is used:

a. Figure O-9 shows the A and B channels from which the Cross Functions are calculated (Octave Power Power Spectrum - Definition 3).

b. Figure O-10 is the Cross Spectrum in Octave (Octave Cross Spectrum - Definition 4).

c. Figure O-11 is the Transfer Function in Octave (Octave Transfer Function Magnitude - Definition 5).

d. Figure O-12 is the Transmissibility Function in Octave (Octave Transmissibility - Definition 6).

e. Figure O-13 is the Coherent Output Power in Octave (Octave Coherent Output Power - Definition 7).

f. Figure O-14 is the Coherence Function in Octave (Octave Coherence - Definition 8).

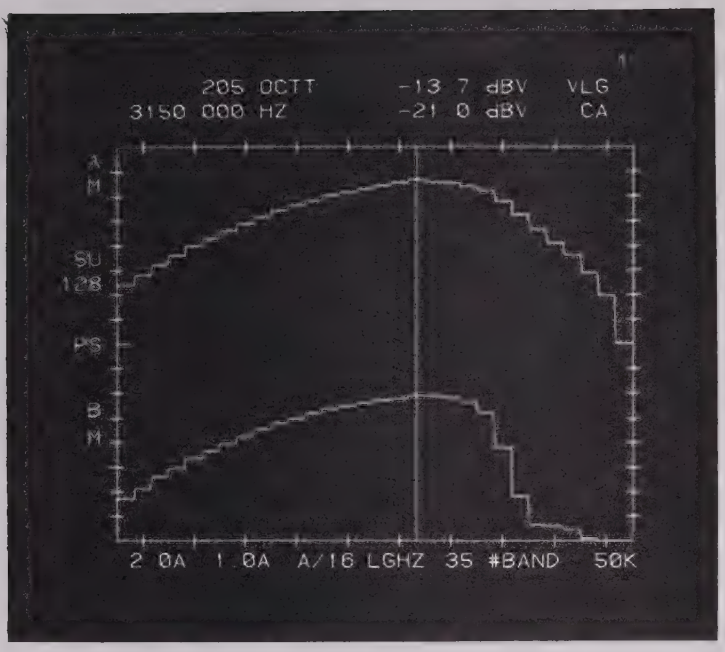



FIGURE O-9

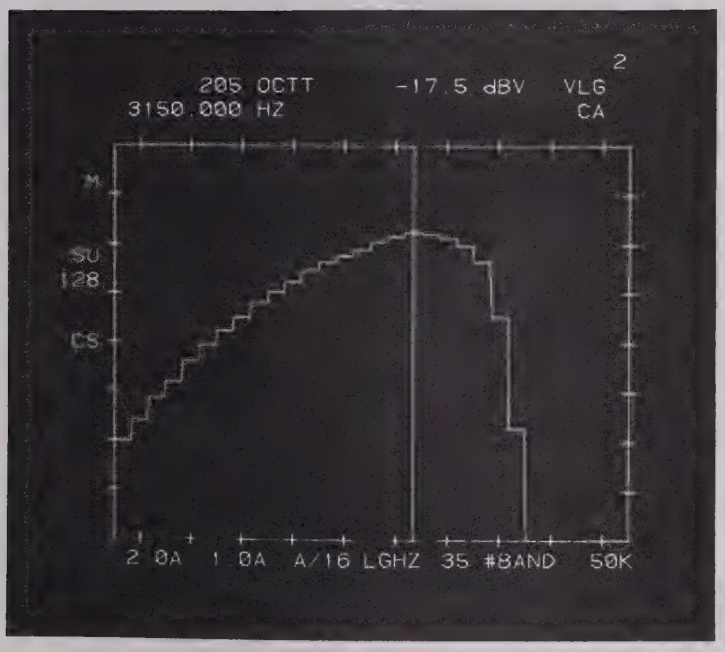



FIGURE O-10

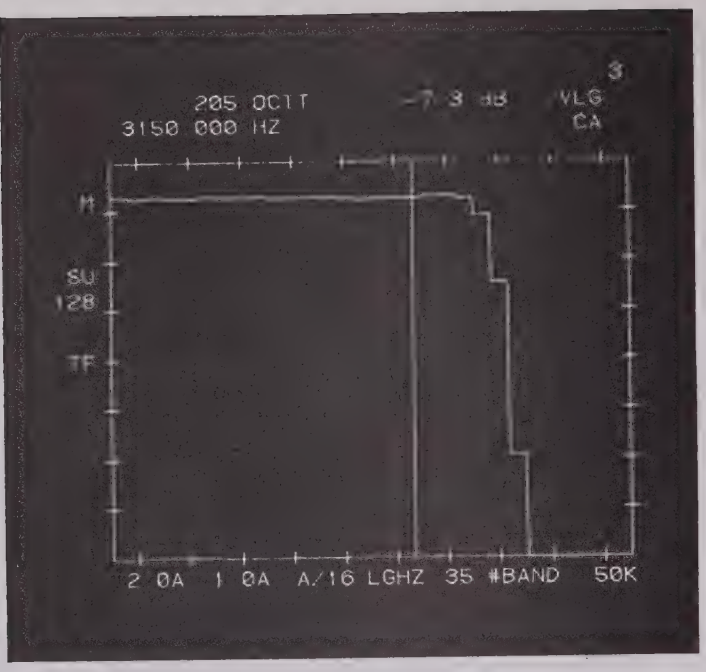



FIGURE O-11

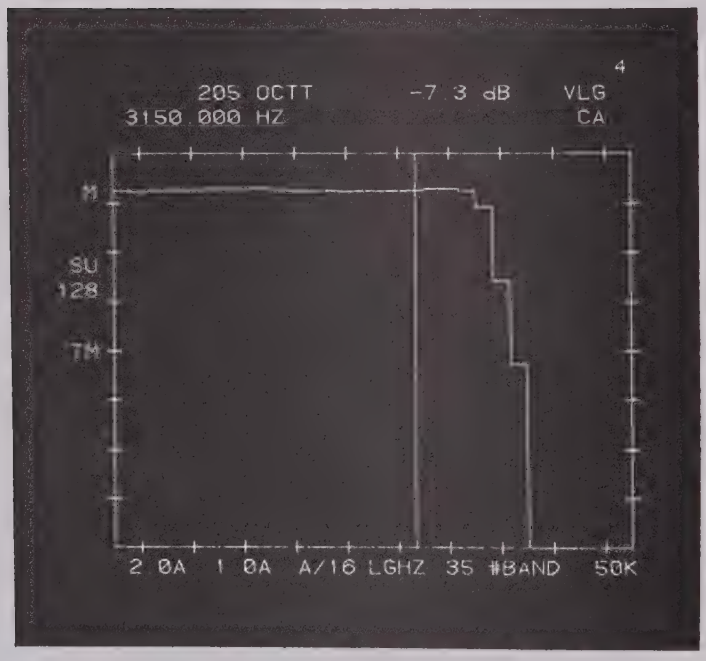



FIGURE O-12

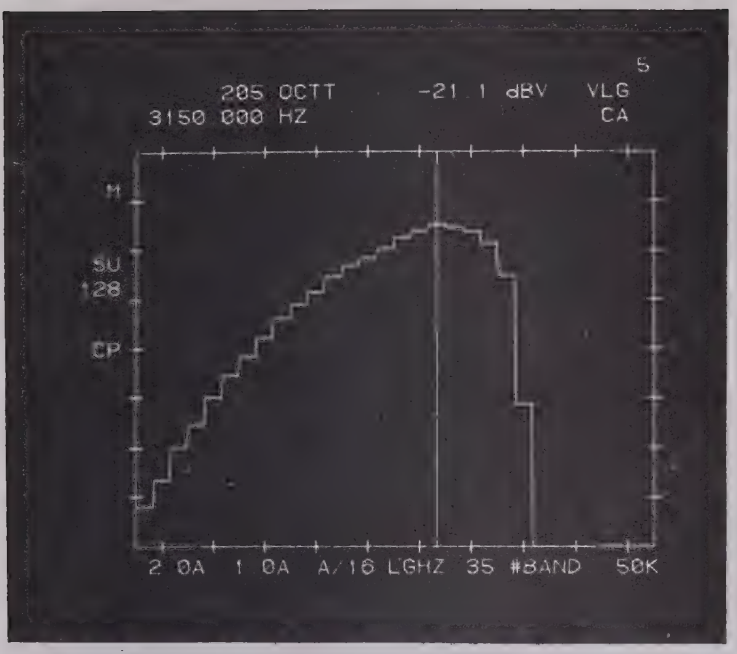



FIGURE O-13

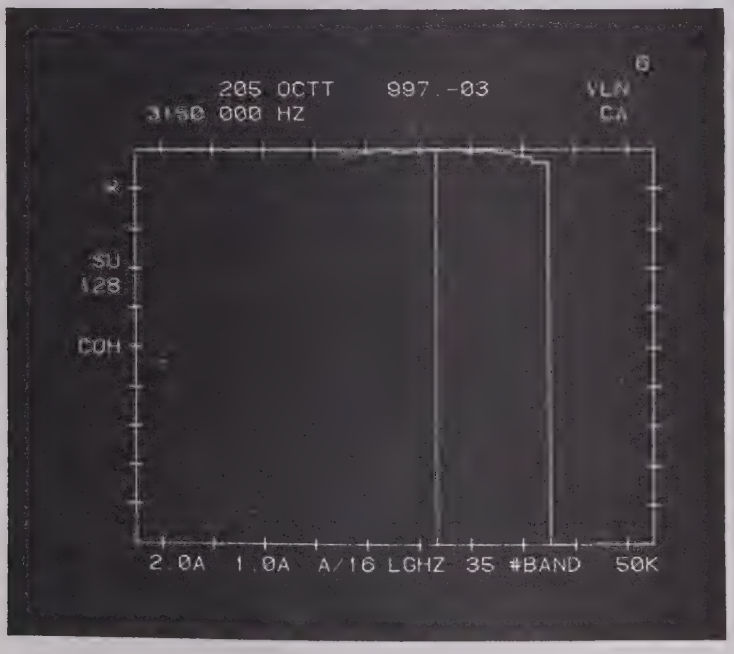



FIGURE O-14

If 1/1 OCTave MODE, 2 Pass Operation, A-Weighted Data is used:

a. Figure O-15 is the Cross Spectrum in Octave (Octave Cross Spectrum - Definition 4).

b. Figure O-16 is the Transfer Function in Octave (Octave Transfer Function Magnitude - Definition 5).

d. Figure O-17 is the Coherent Output Power in Octave (Octave Coherent Output Power - Definition 7).

e. Figure O-18 is the Coherence Function in Octave (Octave Coherence - Definition 8).

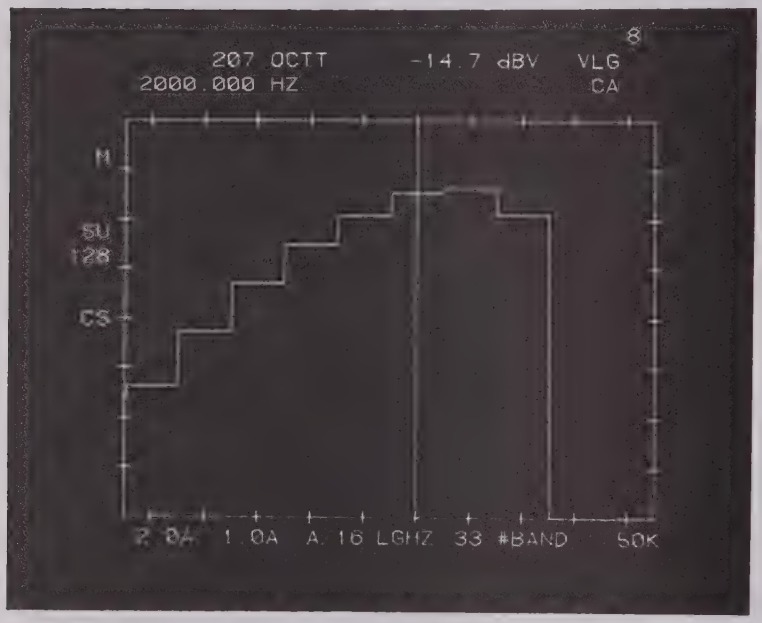



FIGURE O-15

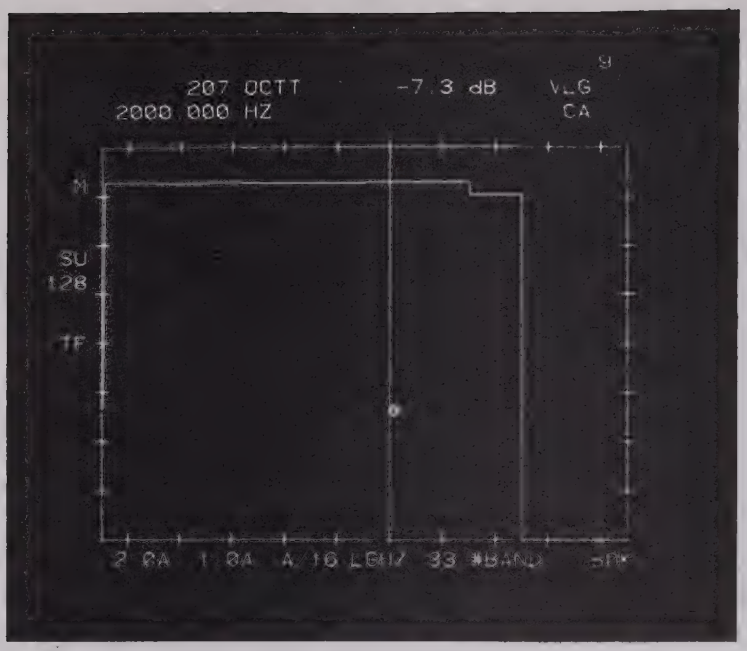



FIGURE O-16

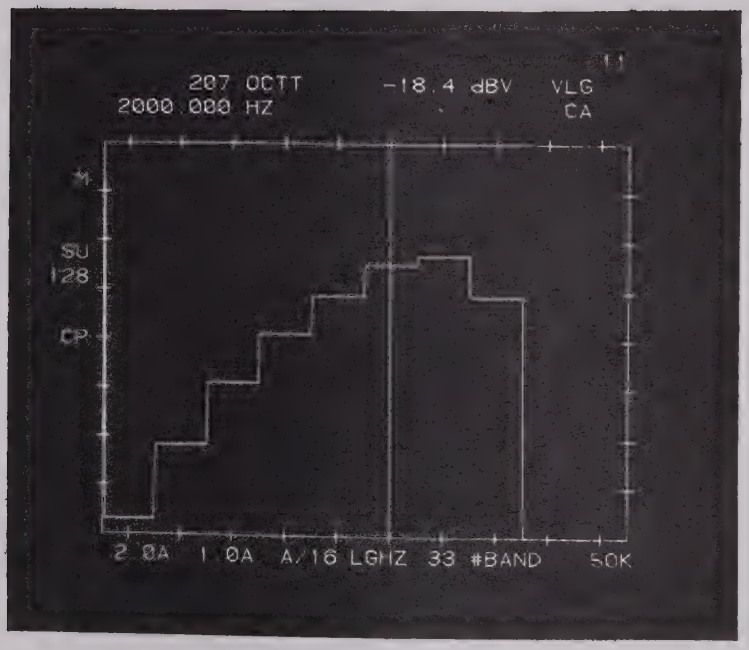



FIGURE O-17

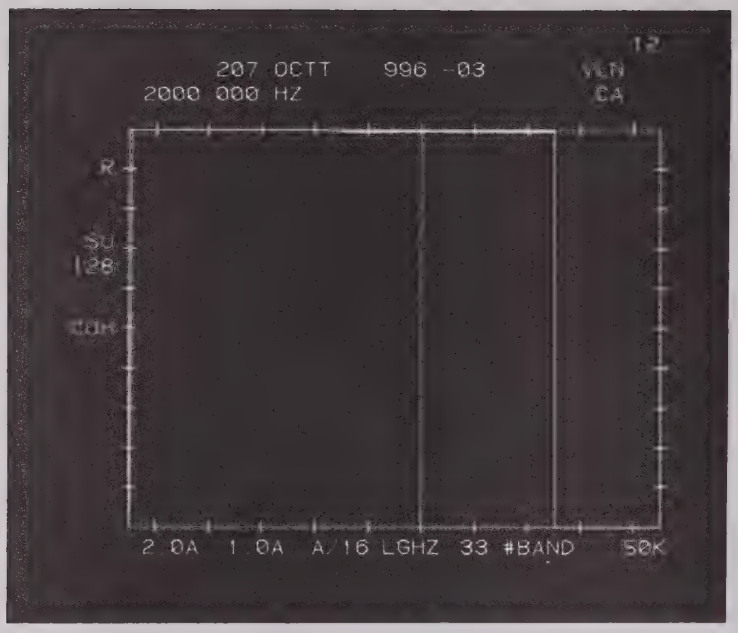

207 OCTT 996 -03
2000 000 HZ
12
VLN
CA
R
SU
28
2 0A 1 0A A/16 LGHZ 33 #BAND 50K

FIGURE O-18

# Option -7 Excitation Source Option

The Excitation Source (Option -7) for the 660B Dual-Channel Analyzer permits selection of one of three digitally controlled signals:

1. Sinewave At Cursor Frequency
2. Pseudo-Random Binary Noise
3. Periodic Binary Noise

The selected signal source is connected to the J109 BNC connector on the rear panel of the 660B. Selection is via the DEF AUX button in the CALCULATION CONTROL section.

## DEF AUX Setting

The DEF AUX button selects the signals and controls the amplitude. The 40 series of DEF AUX controls the signal select and the 100 series of DEF AUX controls the amplitude. The initial wake up condition is 40 and 110 DEF AUX. No signal is present on the output BNC connector.

### A. DEF AUX 40-43 - Signal Select

The different noise sources are enabled by the key sequence:

"X" SET/STORE DEF AUX

where X can be:
- 40 - Excitation Source Off (Wake Up State)
- 41 - Sinewave at the Cursor Frequency
- 42 - Pseudo-Random Binary Noise
- 43 - Periodic Binary Noise

1. 40 DEF AUX - Excitation Source Off - The OFF position is the wake up state of the excitation source; and no signal appears on the rear panel BNC connector.

2. 41 DEF AUX - Sinewave At Cursor Frequency - In this mode of operation, the output of J109 on the rear panel of 660B will be a digitally generated sinewave that will track the frequency at the cursor. The CURSOR TYPE switch must be in either the SINGLE or the HARMONIC position. The sinewave is generated on all ranges, and can also be used wih the optional Nicolet Scientific Digital Range Translator. The resolution of the digital sinewave is 0.25 Hz.

3. 42 DEF AUX - Pseudo-Random Binary Noise - Pseudo-random binary noise is a noise source whose frequency spectrum is flat across the analysis range to within ±3 dB of the spectral mean. With the optional Digital Range Translator invoked, the noise is band limited to concentrate the energy in the band of translation. The noise source will track all frequency windows and expansion ratios.

4. 43 DEF AUX - Periodic Binary Noise - The periodic binary noise source provides a noise pattern that will be repeated for each sample period. This pattern is a fixed 1024 point (1K Mode) or 2048 point (2K Mode) sequence which repeats at a rate specified by the input time window collection period.

## B. DEF AUX 100-199 - Amplitude Controls

The amplitude of the excitation source is fully adjustable from 0.0 V to 9.9 V peak. The amplitude control is achieved via the 100 series of DEF AUX. The wake up state of this series is 110 which is equivalent to 1 V peak. This voltage will be the peak amplitude of the excitation source output. The voltage can be changed in 100 mv increments via the following key sequence:

"N" SET/STORE DEF AUX

where N is any value from 100 to 199. The voltage will be equal to:

Peak Amplitude = (N - 100) x 100 mv

## C. Recall of Source or Amplitude DEF AUX

At any time the current source or amplitude may be recalled. To recall the signal type, the following key sequence is used:

4 RECALL DEF AUX

To recall the amplitude control setting, the following key sequence is used:

10 RECALL DEF AUX

Either of these key sequences recall the setting to the 660B entry field.

D. Error Messages

Error messages may result from the use of the DEF AUX button for the excitation source. Errors appear in inverted type in the entry field. The action which caused the error does not alter any system parameters. Possible errors include:

| Error | Description |
|---|---|
| TURN ON CURSOR | Attempt to turn on sinewave at cursor with the cursor in the OFF position. |
| 40-43 | Attempt to set the 40 series DEF AUX to a number greater than 43. |

# Option -8 Spectrum Calculation


S-1. INTRODUCTION . . . . . S-1
A. Complex Math . . . . . -1
B. Data Editing . . . . . -2
C. Inverse Transform (IFFT). . . . . -2
D. Special Functions . . . . . -2

S-2. OPERATION . . . . . -3
Complex Math . . . . . -3
A. Initialization . . . . . -3
B. 3 Step Operation . . . . . -3
1. Step 1 - "Entry" . . . . . -3
2. Step 2 - "Verification" . . . . . -5
3. Step 3 - "Execution". . . . . -7
C. Buffer Structure . . . . . -7
D. Complex Math Character Set . . . . . -8
E. Math Functions . . . . . -10
F. Complex Math Syntax . . . . . -10
1. Number Formats . . . . . -10
2. Operators . . . . . -12
3. Expressions . . . . . -12
G. Complex Math Scaling . . . . . -13
1. Averager Buffers . . . . . -13
2. Data From Complex Buffer C . . . . . -14
3. Data from Display Memory Buffer D . . . . -16
H. Display Format . . . . . -17

S-3. DATA EDITING
A. Mode 1: Single Point Replacement . . . . . -17
B. Mode 2: Linear Interpolation . . . . . -18

S-4. INVERSE FAST FOURIER TRANSFORM (IFFT) . . . . . -21

S-5. SPECIAL FUNCTIONS . . . . . -21
A. SA . . . . . -21
B. SB . . . . . -24
C. SC . . . . . -24
D. S5 . . . . . -24
E. S6 . . . . . -24
F. Damping . . . . . -27

S-6. APPENDIX - ERROR CODES . . . . . -30
A. Complex Math (CM) . . . . . -30
B. Store Complex Buffer (STO C) . . . . . -30
C. Inverse Transform (IFFT) . . . . . -30
D. Execution (EXC) . . . . . -30
E. Damping (SHIFT 2;9) . . . . . -31
F. Data Editing (SHIFT 2;5 SHIFT 2;6) . . . . . -31
G. Verification (VER) . . . . . -31
H. System . . . . . -32

# Option -8 Spectrum Calculation

## S-1. INTRODUCTION

The Spectrum Calculation Option -8 provides the 660B user with the ability:

- To perform complex or scalar arithmetic operations (+ - * / $\sqrt{\ }$) upon stored or instantaneous frequency data,
- To edit frequency or time domain data resident in the complex buffer (C),
- To perform forward or inverse Fourier transforms upon data resident in the complex buffer (C)
- To compute special purpose functions.

Section 2 discusses operation of Complex Math, Section 3 discusses Data Editing, Section 4 Inverse FFT and Section 5 discusses Special Functions. Section 6 lists Error Codes.

The following is an overview of each Section:

### A. Complex Math

The Complex Math operations may be performed between the current averager buffers:

VA: Power Spectrum A ($P_A$)

VB: Power Spectrum B ($P_B$)

V: Cross Spectrum ($G_{AB}$)

previously stored data:

D: Display Memory Store

C: Complex Buffer Store

and the instantaneous frequency inputs:

A: Complex Frequency Channel A

B: Complex Frequency Channel B

These data are manipulated through the use of the complex math character set in the form of algebraic expressions. User generated equations are entered into Text Field 1 for verification and execution. Upon successful verification (compilation) and execution of an equation, the results are

stored in the Complex buffer C. This data may be examined through the VIEW C control and the desired display format (MAG, ϕ/MAG, R, I, R/I, NYQ). The data resident in C buffer is also available for further computations with the restriction that the final result will be returned to the C buffer.

Example 1:

$C_{old} \times C_{old}: \rightarrow C_{new}$

The new contents of Complex buffer $C_{new}$ now contains $C_{old}^2$. If this equation was executed again, C buffer would contain:

$C_{new} \times C_{new}: \rightarrow C_{new}^2$ or $C_{old}^4$

B. Editing

Either time or frequency data, which is resident in the Complex buffer C, may be modified through the use of the 660B data editing feature. The user may edit data by either single point replacement or linear interpolation between two stored cursor locations. The current display format of VIEW C (R, I, R/I, MAG) selects the particular data for modification.

C. IFFT

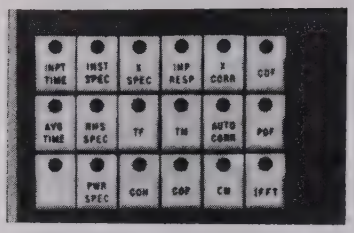
The Complex buffer C is used by the complex math routine and the 660B user as a general purpose storage buffer. Complex as well as scalar functions may reside there. When the inverse FFT (IFFT) feature is evoked, the system assumes that a complex frequency function resides in the C buffer (baseband only). The resultant time function then replaces the frequency data. When the IFFT pushbutton is depressed again, an FFT is performed and the time data is replaced by complex frequency data.

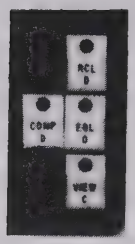
D. Special Functions

A class of problems that require special purpose solutions have also been included within the constraints of the Specutrum Calculation Option. Essentially, unique data handling is applied directly to the 660B data which only has application to a unique class of problems. These controls will be discussed in the Operation Section, S-2.

S-2. OPERATION

Complex Math:




A. Initialization

When the Complex Math (CM) function key is depressed the TEXT mode will be enabled and the Complex buffer C will be cleared. Therefore data to be processed must be collected after Complex Math is selected. The 660B is now ready to accept an algebraic equation. Equations constructed from the valid character set may be 43 characters in length, and are terminated with a colon (44th). Comments may be added after the colon but the maximum field length remains at 44 characters. (Refer to Figure S-1).

B. 3 Step Operation

The operation of Complex Math can be viewed as three steps:

1. Entering the algebraic equation,
2. Verifying the equation, and
3. Executing the equation.

In Figure S-1 power spectrums from Channel A and Channel B are displayed. Referencing Figure S-1 (A) the equation: "VB/VA:" has been verified and executed. This Complex Math equation divides the Averaged Power Spectrum Channel B by the Averaged Power Spectrum Channel A and places the result in the Complex buffer C. The Complex buffer C is denoted by the "CX" on the left edge of the graticule.

A simple example included illustrates each step.

STEP 1: EQUATION ENTRY requires that the 660B user become familiar with the Complex Math character set (See character set) and the Text Entry feature (see Section 18).

Equations may be entered into each text field but only equations resident in Text Field 1 are available for verification. The desired equation can be entered in three ways:

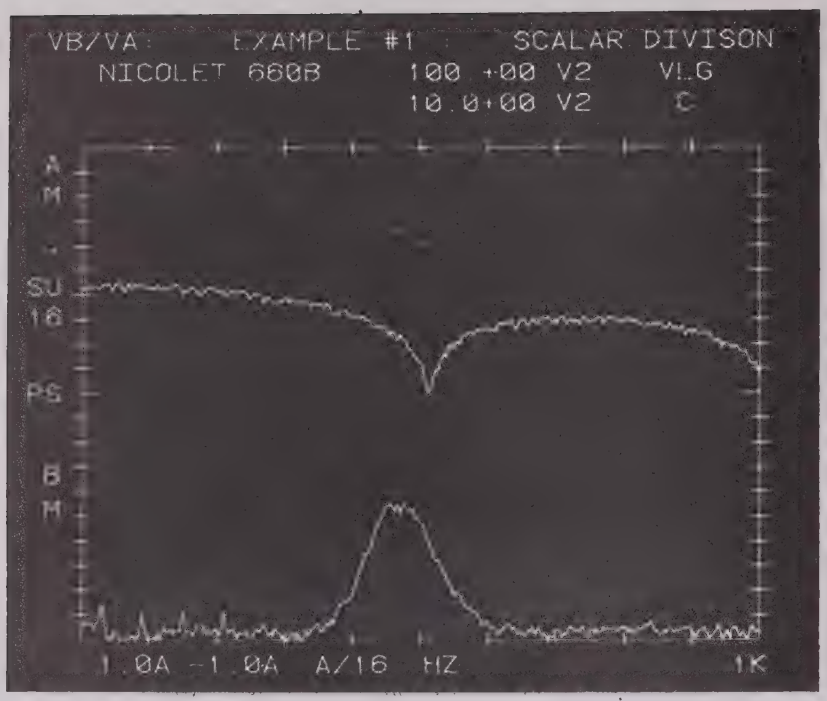



FIGURE S-1.

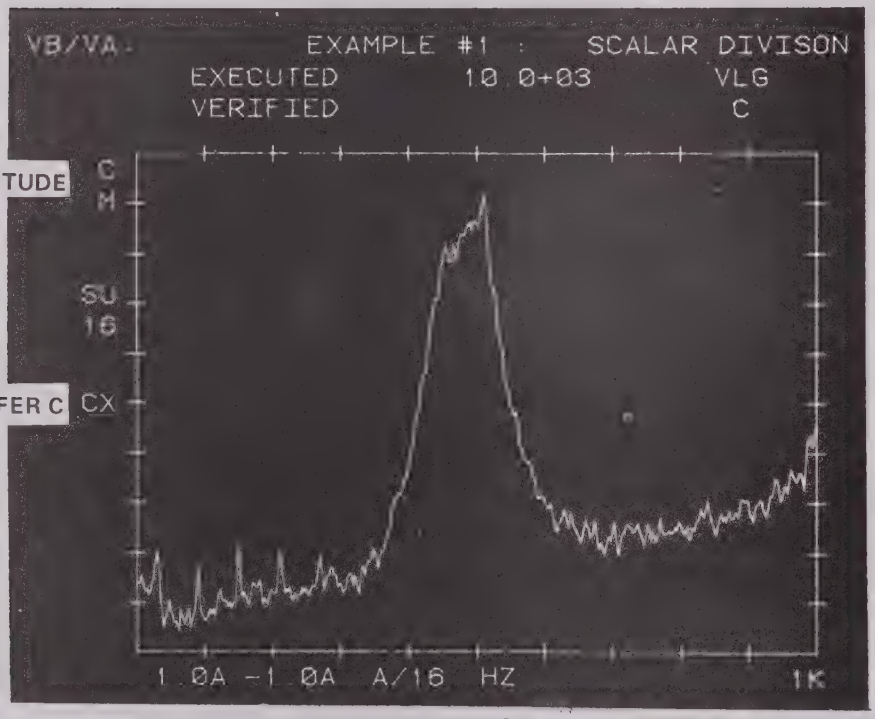



FIGURE S-1A.

1. Typed from Text Key Pad,
2. Read from 160C, or
3. Copied from Text Field 2, 3, 4.

The following example will be used to illustrate entry of an equation. This equation computes the instantaneous cross spectrum ($G_{AB}$).

Example 2: Entering an Equation

1. Depress SYS RST (System Reset).
2. Depress EXPonential AVERAGING
3. Depress CM function key.
   (TEXT MODE is now enabled.)

The following entries will use the TEXT key pad and the CALCULATION CONTROL keys:

| | | | |
|---|---|---|---|
| 4. | A | : | ABC |
| 5. | # | : | 2nd char. '#: |
| 6. | SHIFT 2 MULT | : | |
| 7. | B | : | 2nd char. ABC |
| 8. | : | : | 3rd char. '#: |

(Refer to Figure S-2.)

STEP 2: VERIFICATION performs a compiliation of the equation in Text Field 1. The procedure checks the equation for character and syntax errors and obtains the current scale factors. It is important to note that scale factors are assigned at the TIME OF VERIFICATION. This will be discussed in more detail later in this section.

Once an equation has been verified, the 660B user may continually execute the same equation with only two key strokes rather than repeated retyping.

The verification procedure places a valid string message VERIFIED in the cursor field and exits the TEXT mode when the equation has compiled with no errors. When an error has occurred, the appropriate error message is positioned in the cursor field and the first invalid character of the equation will appear in inverse video. The error messages and their causes are listed in section S-6, Appendix 1. The equation should then be corrected and verification attempted again. Upon successful verification, the ERROR message will be cleared and message VERIFIED will be posted. (Note: To clear the ERROR message, toggle the cursor on/off control.)

9. Depress SHIFT 2 VER (The message VERIFIED should appear in the cursor field. See Figure S-3).

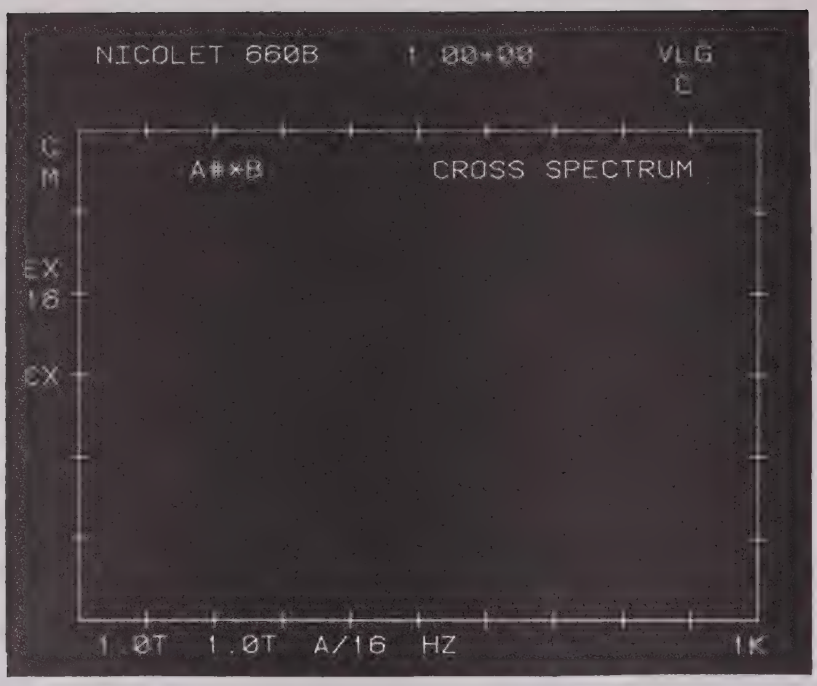



FIGURE S-2.

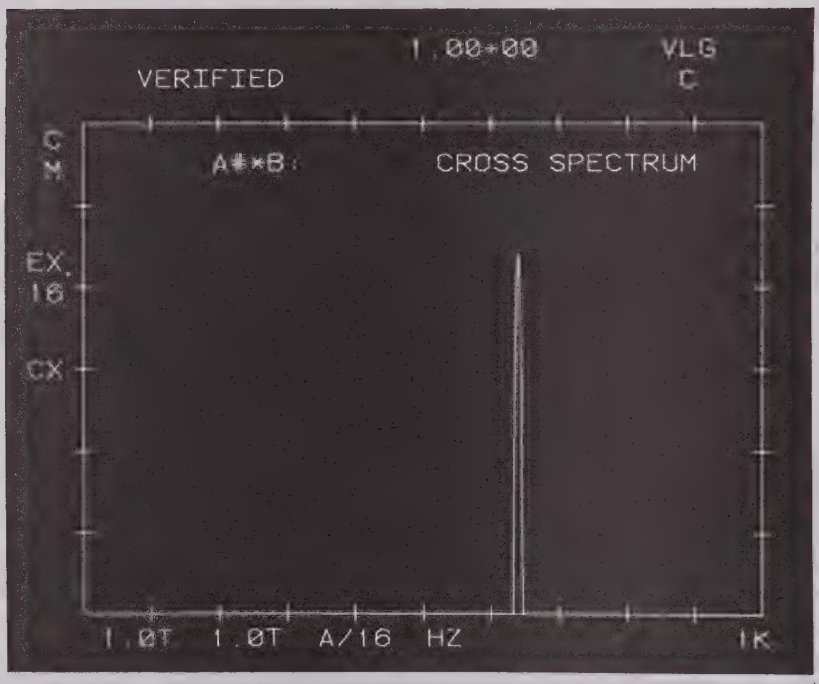



FIGURE S-3.

NOTE: In Figures S-2 and S-3, the Text 1 Field Position has been moved using the SHIFT 1 MOVE command.

STEP 3: EXECUTION of an equation has two modes of operation which depend on the type of data involved. First, whenever instantaneous data is part of an expression, the equation will be referred to as "LIVE". Execution is initiated by depressing the START average control. Second, when only averaged or stored data defines an expression, the equation will be referred to as "STATIC". In this case, execution is initiated by depressing SHIFT 2 and EXC.

Live equations allow the 660B user to manipulate the instantaneous complex frequency components (i.e. real, imaginary) from Channel A and Channel B. The results of these equations are then averaged in the Complex buffer C.

Upon successful execution of a static equation, the message EXECUTED is posted in the entry field. If execution of a live equation is attempted by SHIFT 2 and EXC, an error message MUST AVERAGE will appear reminding the user to start the averager. Once an equation has been verified, it may be executed as many times as desired by either starting the averager or depressing SHIFT 2 and EXC. In addition, Text Field 1 may be edited or eliminated from the display without effecting the execution of a previously verified equation.

Example 2 (continued): Execution

10. Depress START (Refer to Figure S-3).
    (NOTE: Since this equation involves the instantaneous inputs A and B, it is a LIVE equation.)

11. To display the result depress the VIEW C control and select the display format MAG. (NOTE: In this example, the internal test signal was used as the data sources for for Channel A and B. This result will be identical to the normal cross spectrum display.)

### C. Buffer Structure

There are eight internal data buffers that can be addressed through the complex math character set. These are:

| I/O Port Address | Definition | Length[1] | CM Label |
|---|---|---|---|
| 4 | Averaged Power Spectrum A | 512 PTS | VA |
| 5 | Averaged Cross Spectrum (Real) | 512 PTS | VR |
| 6 | Averaged Cross Spectrum (Imaginary) | 512 PTS | VI |
| 7 | Averaged Power Spectrum B | 512 PTS | VB |
| 8 | First Display Memory (Real) | 512 PTS | DR |
| 9 | Second Display Memory (Imaginary) | 512 PTS | DI |
| C | First Complex Memory (Real) | 512 PTS | CR |
| D | Second Complex Memory (Imaginary) | 512 PTS | CI |

[1]512 points plus DC.

In addition, the instantaneous complex frequency data (LIVE data) from Channel A and Channel B may also be addressed.

| Definition | Buffer Type | CM Label |
|---|---|---|
| Instantaneous Channel A (Complex) | Complex | A |
| Instantaneous Channel B (Complex) | Complex | B |

D. Complex Math Character Set (CM)

The CM character set uses a simple scheme to address scalar as well as complex arrays. Single character labels refer to complex quantities.

| CM Lable | Definition | Buffer Type |
|---|---|---|
| A | Instantaneous A | Complex |
| B | Instantaneous B | Complex |
| C | Complex Buffer | Complex |
| D | Display Memory Buffer | Complex |
| V | Cross Spectrum Buffer | Complex |
| T[1] | Transfer Function | Complex |

To address the real or imaginary parts of these quantities, a second character either R or I is added.

| CM Label | Definition | Buffer Type |
|---|---|---|
| AR | Instantaneous A Real | Scalar |
| AI | Instantaneous A Imaginary | Scalar |
| BR | Instantaneous B Real | Scalar |
| BI | Instantaneous B Imaginary | Scalar |
| CR | Complex Buffer Real | Scalar |
| CI | Complex Buffer Imaginary | Scalar |
| DR | Display Memory Buffer Real | Scalar |
| DI | Display Memory Buffer Imaginary | Scalar |
| VR | Cross Spectrum Buffer Real | Scalar |
| VI | Cross Spectrum Buffer Imaginary | Scalar |
| TR[1] | Transfer Function Real | Scalar |
| TI[1] | Transfer Function Imaginary | Scalar |

[1]Transfer function is computed dynamically in CM equations.

Also, the magnitude of any of the complex quantities may be addressed by adding the character M.

| CM Label | Definition | |
|---|---|---|
| AM | Instantaneous A Magnitude | $\sqrt{AR^2 + AI^2}$ |
| BM | Instantaneous B Magnitude | $\sqrt{BR^2 + BI^2}$ |
| CM | Complex Buffer C Magnitude | $\sqrt{CR^2 + CI^2}$ |
| DM | Display Memory Buffer D Magnitude | $\sqrt{DR^2 + DI^2}$ |
| VM | Cross Spectrum Buffer V Magnitude | $\sqrt{VR^2 + VI^2}$ |
| TM[1] | Transfer Function Magnitude | $\sqrt{TR^2 + TI^2}$ |

Additionaly, the averaged power spectrum buffers are addressed:

| CM Label | Definition | Buffer Type |
|---|---|---|
| VA | Averaged Power Spectrum A | Scalar |
| VB | Averaged Power Spectrum B | Scalar |

The following list completes the CM character set.

| CM Label | Definition |
|---|---|
| )> | Right Parenthesis |
| (< | Left Parenthesis |
| : | String Terminator (Colon) |
| , | Numerical Separator (Comma) |
| . | Decimal Point |
| * | Multiplication (SHIFT 2, MULT) |
| / | Division (SHIFT 2, DIV) |
| + | Addition |
| - | Subtraction |
| √‾ | Square Root |
| # | Conjugate |
| E | Letter "E" Exponent (Floating Point Notation: E±XX) |
| 0-9 | Numerics |

---

[1]Transfer function is computed dynamically in CM equations.

E. Math Functions

The Complex Math functions are defined below:

(NOTE: (a + ib) and (c + id) represent two unique complex numbers.)

1. Complex Addition/Subtraction:

$$(a + ib) \pm (c + id) = (a \pm c) + (b \pm d)i$$

2. Complex Multiplication:

$$(a + ib) * (c + id) = (ac - bd) + (bc + ad)i$$

3. Complex Division:

$$(a + ib)/(c + id) = \frac{(ac + bd)}{c^2 + d^2} + \frac{(bc - ad)i}{c^2 + d^2}$$

4. Complex Conjugate:

If $Z = (a + ib)$ then $Z\# = (a - ib)$

5. Complex Square Root:

If $Z = r(\cos \phi + i \sin \phi)$

where $r = \sqrt{a^2 + b^2}$

and $\phi = \tan^{-1} b/a$

then $\sqrt{Z} = \sqrt{r}(\cos \phi/2 + i \sin \phi/2)$

F. Complex Math Syntax

The 660B CM feature performs complex or scalar operations upon arrays of data as defined by the user equations. Certain protocol and syntax exist in the generation of these equations.

1. Number Formats

Constants - Scalar and complex constants may be part of any CM equation. Integer, real, and floating point are all acceptable. Table S-1 lists some valid format examples.

TABLE S-1

The following are all valid CM equations:

| | | |
|---|---|---|
| VA×-2: | : | Scalar Integer |
| VA×0.2 E+01: | : | Scalar Floating Point |
| V×(212.0E-03, 1.2E-01): | : | Complex Floating Point |
| C×(0, -1): | : | Complex Integer |

Signed floating point constants are limited to 14 characters plus the sign with the following format:

```
  ± X.XXXXXXXXE±XX
  ↑      ↑
sign     9 Digits Plus Decimal Point
         (The decimal point position is arbitrary.)
```

The 660B floating point range is 1E - 38 < X > 1E + 38 with only six significant digits being recognized.

Signed integer constants are limited to 14 characters including sign:

```
ex) ±XXXXXXXXXXXXX
        ↑
    14 Characters
```

Real constants follow the same format with a decimal point in place of any digit (i.e. X). (Except the first if a sign is present.)

```
ex)   .05  - legal
     -.05  - illegal
    -0.05  - legal
```

Complex floating point and integer constants follow the same format:

ex) Complex Floating Point (F.P. Real, F.P Imaginary)
(-1.2E+02, 1.99E-03)

ex) Complex Integer (R, I)
(7, -2)

ex) Mixed Modes Are Valid:
(1.7, -2)
(-2.11E-07, -1.11)

## 2. Operators

The CM operations are broken into two categories; primary <+, -, x, ÷>, and secondary < $\sqrt{\ }$, #>. The following rules apply when formulating a valid equation.

1. Every equation must have at least one primary operator.

   ex) $\sqrt{\ }$ C :
   is NOT VALID, however,

   $\sqrt{\ }$(C + 0,0) :
   is VALID.

   In this equation the desired result is the complex square root of the data contained in C buffer. Therefore, the addition of zero does not effect the result.

2. Secondary operations are applied before primary operations of the same level.

   ex) $\sqrt{\ }$C + D# :

   In this example the complex square root of C is added to the conjugate of D.

   ex) $\sqrt{\ }$(C + D#) :

   In this example the data in C buffer is added to the conjugate of D and the complex square root is taken upon the result.

## 3. Expressions

CM equations may be constructed with parentheses nested four levels deep and with two temporary results.

ex) ((((A - B) + D) + (1, 0)) x (7.12, -0.25)) :

This expression illustrates a live equation with maximum nesting.

ex) ((V x D) x (2.1, .06)) + (( D x D) x (1.6,-2)) :

This expression illustrates two temporary results. NOTE: C buffer was not used in this expression.

This allows C buffer to be used for temporary results during execution of the equation. If C buffer was used, then only one temporary result would be allowed:

ex) C + ((D x V) x (1,2)) :

All Complex Math equations must be terminated with a colon. The colon is used to terminate the algebraic expression and provide a separator for user comments.

1. Complex and scalar, arrays or constants, may not be mixed in the same expression.

   ex) V × 6.0 :

   Upon verification this equation will generate the error ILLEGAL because V is a complex array and 6.0 is a scalar constant.

   ex) V × 6.0, 0: or V × (6.0, 0):

   Are both valid equations.

   NOTE: Parentheses are not required to delineate complex constants.

2. Real and imaginary buffers may be used independently and are treated as scalar arrays.

   ex) (DR × 1.2) + (CR × 1E-02):

   This equation will generate a real result and the solution will replace the CR buffer.

   NOTE: Any data present in the CI (C Imaginary) buffer prior to execution of this equation will be cleared due to the real result.

   ex) (DR × CI)/2.1E-03:

   This equation will generate an imaginary only result in the CI buffer.

   NOTE: Any data present in the CR (C Real) buffer prior to execution of this equation will be cleared due to the imaginary result.

G. Complex Math Scaling

Scale factors are applied to all complex math equations at the time of verification. This is an extremely important statement and care must be taken by the 660B user to ensure consistent results.

1. Averager Buffers

The contents of the averager buffers are always well defined:

Power Spectrum A (VA)
Cross Spectrum Real (VR)
Cross Spectrum Imaginary (VI)
Power Spectrum B (VB)

The data in these buffers are defined as raw data (i.e. unscaled). A "state table" is maintained which contains the proper information (attenuator settings, number of averages taken, EU/V settings) to scale this data and produce numerically correct results.

When reference is made to a data buffer in a complex math equation, the scale factor is computed from the current state of the system, and automatically applied. Therefore, if the system state is changed (i.e. AVERAGER mode), the complex math equation must be verified again. Data from the averager buffers will always be scaled as power. (Reference Chapter 19, for scaling equations.)

| CM Label | Definition |
|---|---|
| VA | Averaged Power Spectrum A |
| VB | Averaged Power Spectrum B |
| V | Averaged Cross Spectrum $G_{AB}$ |

RMS spectrum (voltage) is merely the square root of the power spectrum:

ex) $\sqrt{VA}$ = RMS Spectrum of A
$\sqrt{VB}$ = RMS Spectrum of B

2. Data From C Buffer

Data in the C (complex) buffer is always assumed to be scaled. Any data stored by STO C is always automatically scaled first. Results of equations are always scaled. This is important if data is read into C buffer from an external device (i.e. RS232-C or IEEE488 Interfaces).

Table S-2 is a list of the actions caused by STO C for each applicable 660B function. Depressing STO C while viewing an invalid function will result in the error message, CAN'T STORE C. Note, that STO C always stores scaled frequency domain data in the complex buffer. If C is read out of the interfaces (RS232-C or IEEE488), no scaling is required.

In Table S-2, 1ST TRACE refers to the upper trace or the only trace currently being displayed on the CRT. This may be RCL D data, channel A or B. 2ND TRACE refers to the lower trace of a two trace display.

TABLE S-2

| 660B MODE | FUNCTION | STO C ACTION |
|---|---|---|
| SIG EHN AVG TIME | F* (1ST TRACE) | CR, CI |
| 1K CROSS SPECTRUM | CROSS SPEC REAL<br>CROSS SPEC IMAG | CR<br>CI |
| TRANSFER FUNCTION | TRANS FUNC REAL<br>TRANS FUNC IMAG | CR<br>CI |
| SIG ENH/1K | INST | DISPLAY CHANNEL A<br>AR → CR<br>AI → CI<br><br>DISPLAY CHANNEL B<br>BR → CR<br>BI → CI<br><br>DISPLAY CHANNEL A & B<br>DISPLAY FORMAT<br>REAL AR → CR BR → CI<br>IMAG AI → CR BI → CI<br>MAG AM → CR BM → CI |
| 1K | RMS SPEC | 1ST TRACE → CR<br>2ND TRACE → CI |
| | POWER SPEC | 1ST TRACE → CR<br>2ND TRACE → CI |
| IR | TRANS FUNC REAL<br>TRANS FUNC IMAG | CR[1]<br>CI |
| TM | | 1ST TRACE → CR<br>2ND TRACE → CI |
| COH | | 1ST TRACE → CR<br>2ND TRACE → CI |
| RCL D | | DR → CR<br>DI → CI |

*F = Fourier Transform

[1]To view Impulse Response (IR), depress IFFT.

### 3. Data From D Buffer

Unlike the averager buffers whose contents are well defined, D buffer may contain complex or scalar data; power, voltage, or dimensionless data; or time or frequency domain data. Nonetheless, if buffer D is used in an equation, the data from buffer D will be correctly scaled.

Table S-3 defines the contents of D and the associated CM labels or equations. Note, that D is always treated as if it held complex data. (Refer to Section 19, Table 19-14 (B) for complete details for Display Memory Store.)

TABLE S-3

| STORED D FROM | COMPLEX MATH DEFINITIONS |
|---|---|
| POWER SPECTRUM A & B | DR = VA = POWER SPECTRUM OF A<br>DI = VB = POWER SPECTRUM OF B |
| RMS SPECTRUM A & B | DR = $\sqrt{\text{VA}}$ = RMS SPECTRUM OF A<br>DI = $\sqrt{\text{VB}}$ = RMS SPECTRUM OF B |
| CROSS SPECTRUM | D = V CROSS SPECTRUM |
| TF | D = T TRANSFER FUNCTION |
| COH | DR = COH = VM x VM/(VA x VB) |
| COP | DR = COP = VM x VM/(VA x VA) |
| TM | DR = TM = $\sqrt{(\text{VB/VA})}$ |
| INSTANT SPEC | See Excerpt for Table 19-14 (B), Chapter 19. |
| IMP RESP (IR) | D = IR (TIME)* |

*Time Data in D:

Complex Math operations are only defined in the frequency domain, but it is possible to add and substract time data. Thus if impulse response is stored in D, by depressing VIEW C and IFFT, the C buffer is now in the time domain format. The CM equation "D + C :" will correctly add D to C in time.

H. Display Format

Because voltage (Vc) or power ($Vc^2$) data may reside in the C buffer special define auxiliary (DEF AUX) codes have been assigned to format the log magnitude display while in VIEW C.

| DEF AUX | DEFINITION |
|---|---|
| 210 | 10 log (C) |
| 211 | 20 log (C) |

These controls do not effect the data resident in C, only the display format.

## S-3. DATA EDITING

Data editing can be used to enter data or modify any data resident in the Complex buffer (C). Data editing uses two modes of operation that may be used independently or simultaneously to form "complex frequency" or time[1] wave forms.

### 1. Mode 1: Single Point Replacement

While viewing buffer C (VIEW C) any spectrum point may be replaced by a new value. The replacement operation is performed as follows:

A. Select the Display Format - (R, I, R/I, MAG, IFFT).

B. Position the cursor on the point of interest.

C. Enter the desired new value into the entry field through the CALCULATION CONTROL key pad.

D. Depress, SHIFT 2 then 5.

The new value will replace the old value.

---

[1]It is possible to create time functions through data editing that DO NOT conform to the sampling criteria. In this case, aliased frequency spectra will result.

The following is a simple example using data editing to create a time domain signal from its frequency spectrum. Once created, this data may also be used in complex math equations.

ex) Create an AM modulated sine wave.

1. Depress: SYS RST
2. Depress: CM (Text is Enabled)
3. Depress: TEXT (TEXT Off)
4. Depress: VIEW C (Denoted by "CX")
5. Depress: REAL (Denoted by "CR")
6. Select: 1K Hz Bandwidth
7. Position Cursor To: 50 Hz (Figure S-4)
8. Enter into the Entry Field: 1.0
9. Depress: SHIFT 2 then 5
10. Position the Cursor To: 40 Hz
11. Enter into the Entry Field: 0.7
12. Depress: SHIFT 2 then 5
13. Position the Cursor To: 60 Hz
14. Depress: SHIFT 2 then 5 (refer to Figure S-5)
15. Depress: IFFT and adjust the GAIN (refer to Figure S-6)

## 2. Mode 2: Linear Interpolation

As in Mode 1, Mode 2 operation only applies to the C buffer. Mode 2 assumes that a cursor value has been stored in cursor location 1 and 2. Mode 2 performs a point replacement of the data values between cursor locations 1 and 2 as in the following Linear Interpolation Formula.

Linear Interpolation Formula:

$$V(X) = V(X_1) + (X - X_1) * f[X_2, X_1]$$

where: $V(X)$ = New Value at Position X

$V(X_1)$ = Value at Base Cursor Location, $(X_1)$

$$f[X_2, X_1] = \frac{V(X) - V(X_1)}{X - X_1}$$

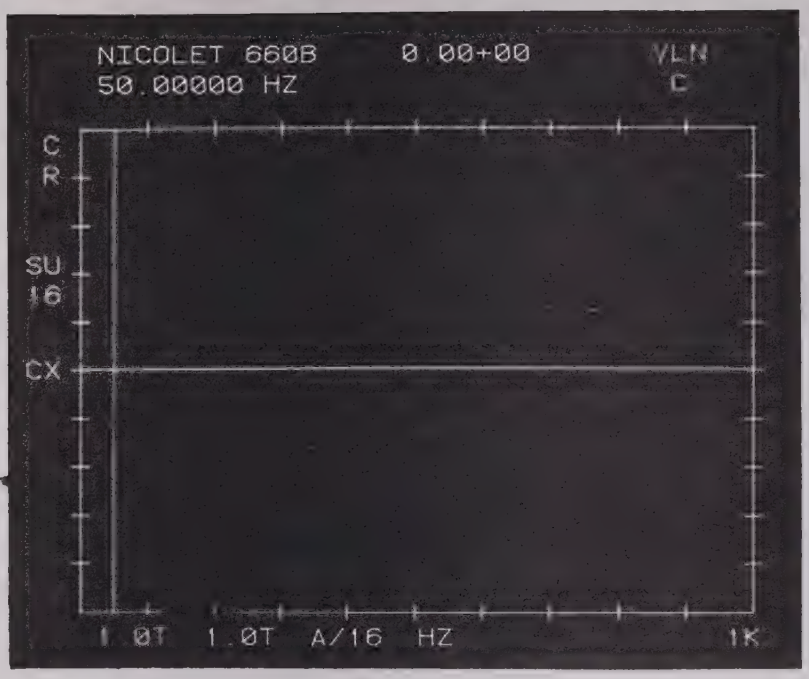



FIGURE S-4.

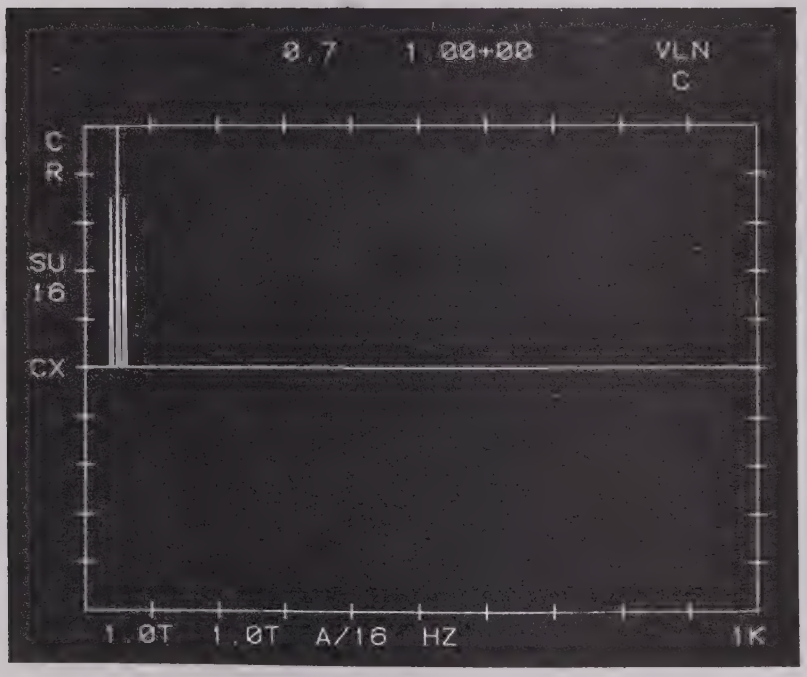
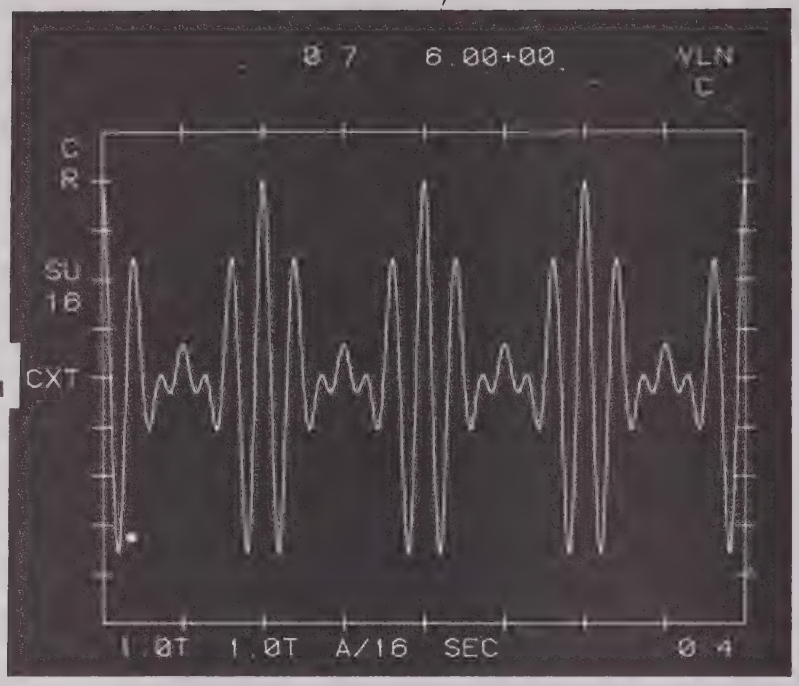



FIGURE S-5.




TIME SPECTRUM

FIGURE S-6.

NOTE: In referring to Figure S-6, the label "CXT" on the left graticule denotes that C buffer now contains a 1024 point time spectrum.

To perform the point by point replacement of the data values between cursor locations 1 and 2:

1. Select the display format (R, I, R/I, MAG, IFFT)
2. Position the cursor to the desired starting point
3. Store Cursor 1: 1 SET/STORE CUR/LOC (Figure S-7)
4. Position the cursor to the desired end point
5. Store Cursor 2: 2 SET/STORE CUR/LOC
6. Depress: SHIFT 2 then 6 (Figure S-8)

Both single point replacement and linear interpolation affect the data in C in a manner consistent with the display format:

Real - Only Real data affected (CR).
Imaginary - Only Imaginary data affected (CI).
R&I - Both affected.
Mag or /Mag - Magnitude is changed by multiplying both R&I by the appropriate factor to achieve the desired result. This preserves phase ($\tan^{-1}$ I/R).

NOTE: While the system is interpolating, the message WORKING will be posted in the cursor field. Upon completion, the message will be cleared.

## S-4. INVERSE FAST FOURIER TRANSFORM (IFFT)

The IFFT function may only be used with data resident in the Complex buffer C. This function assumes that a complex frequency spectrum exists in C, for example, transfer function, cross spectrum, created data (see Figure S-9). When the IFFT function is evoked (IFFT LED is on) the resultant 1024 point time function replaces the frequency data and is available for transfer via the I/O ports (Figure S-10). The display is time zero centered with buffer CI (I/O buffer D) containing time points 0 → 512 and buffer CR (I/O Buffer C) containing time points 513 → 1023. When the IFFT button is depressed again (IFFT LED is off), an FFT is performed and the time data is replaced by complex frequency data.

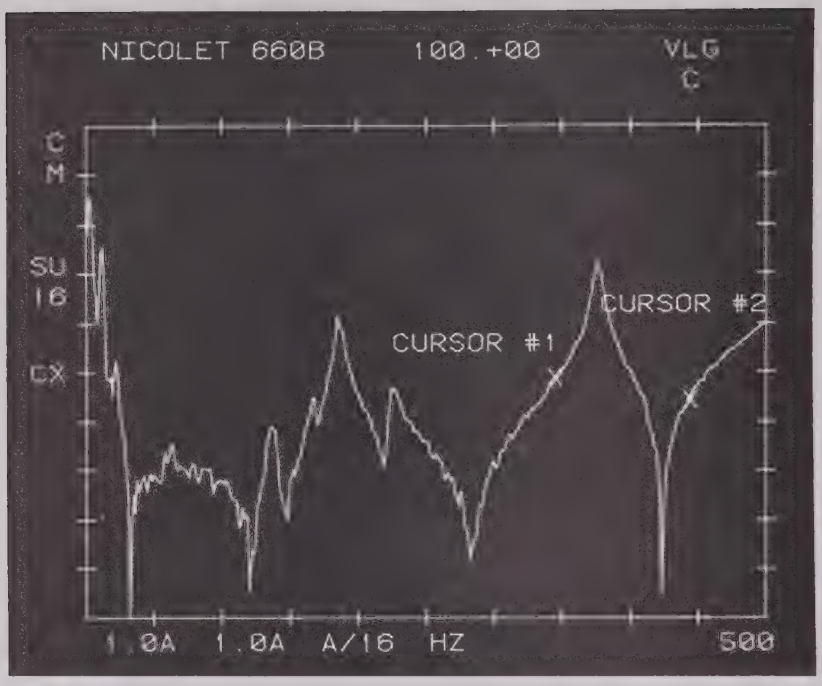



FIGURE S-7.

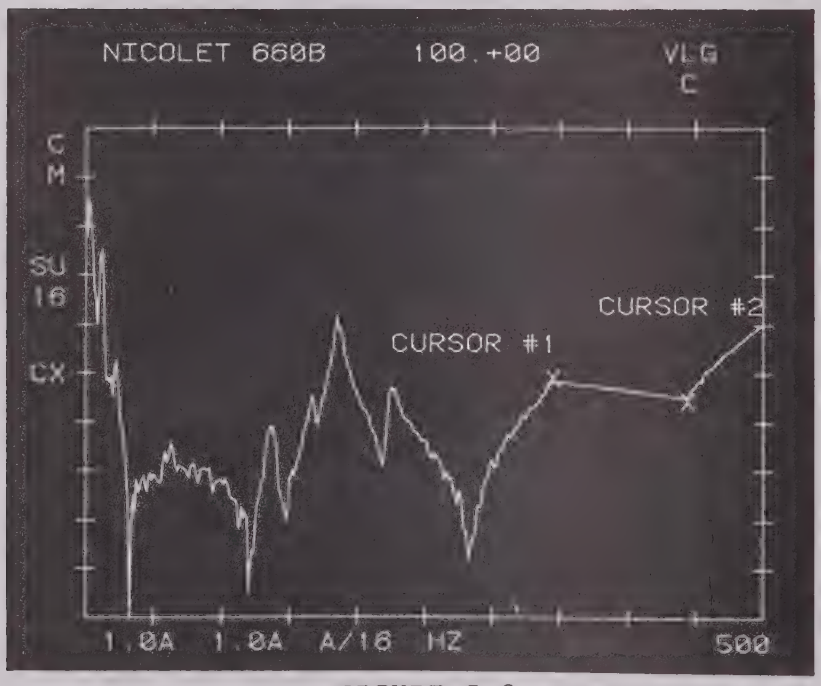



FIGURE S-8.

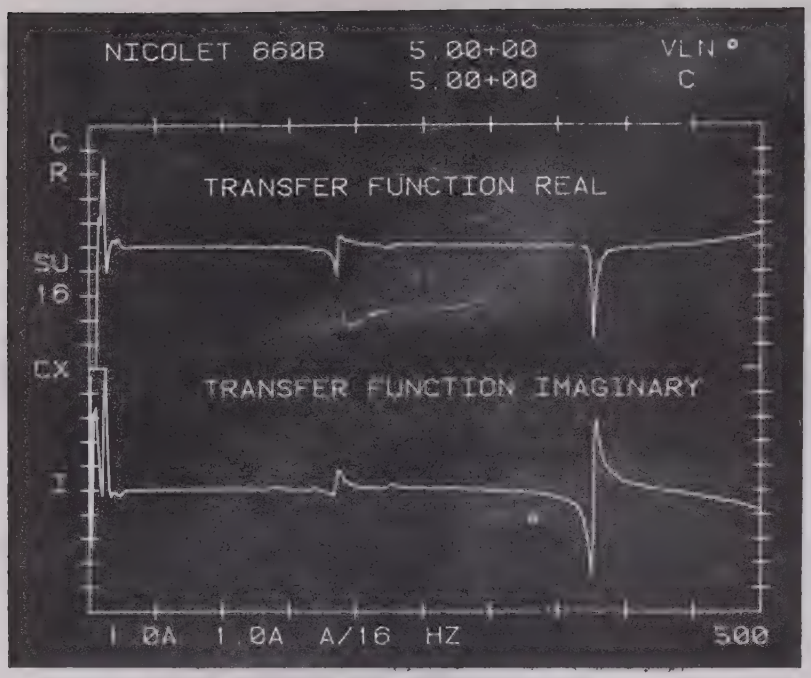



FIGURE S-9.

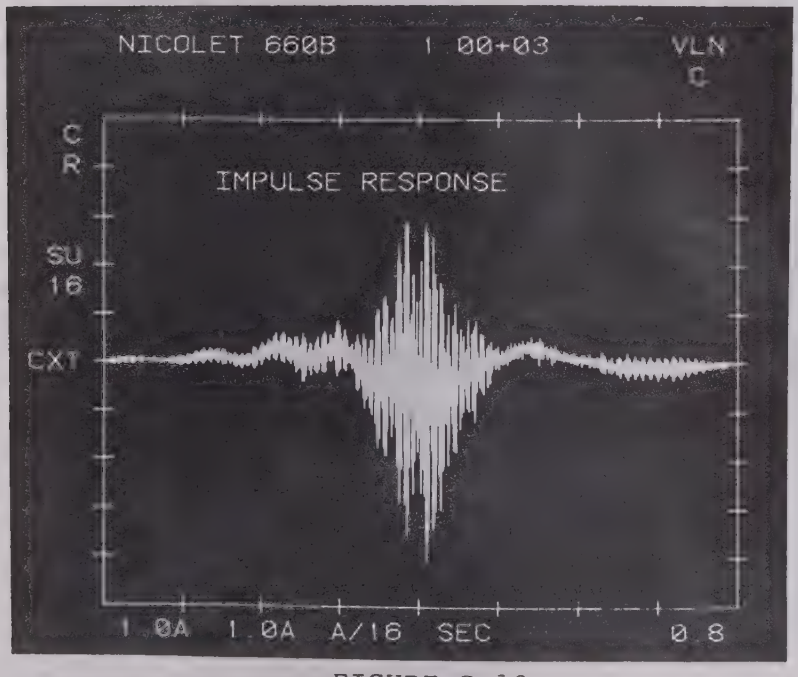



FIGURE S-10.

## S-5. SPECIAL FUNCTIONS

The following is a list of unique complex math functions that perform special data handling. Each must be verified before execution.

A. SA - Places Power Spectrum Channel A into Complex Buffer CR.

Places Power Spectrum Channel B into Complex Buffer CI

This function is executed as a live equation (i.e. after every averager cycle).

In Figure S-11 the phase/magnitude ($\phi$/MAG) display format has been selected for the Complex buffer C while the (CM Special SA) is executing. The display shows:

$$MAG = \sqrt{(P_A)^2 + (P_B)^2}$$

$$\phi = \text{ARC TAN } P_B/P_A$$ [1]

where: $P_A$ = Power Spectrum of Channel A
$P_B$ = Power Spectrum of Channel B

B. SB - Performs the same operation as SA except that it is a static equation, therefore execution is performed on a one-shot basis by SHIFT 2 EXC.

C. SC - Performs absolute value [$\sqrt{C^2}$] upon any data resident in C buffer. Refer to Figure S-12 and S-13 as an illustration. Execution is performed on a one-shot basis by SHIFT 2 EXC.

---

[1] The attenuator settings of channel A and channel B should be set identically for this setup to be scaled properly.

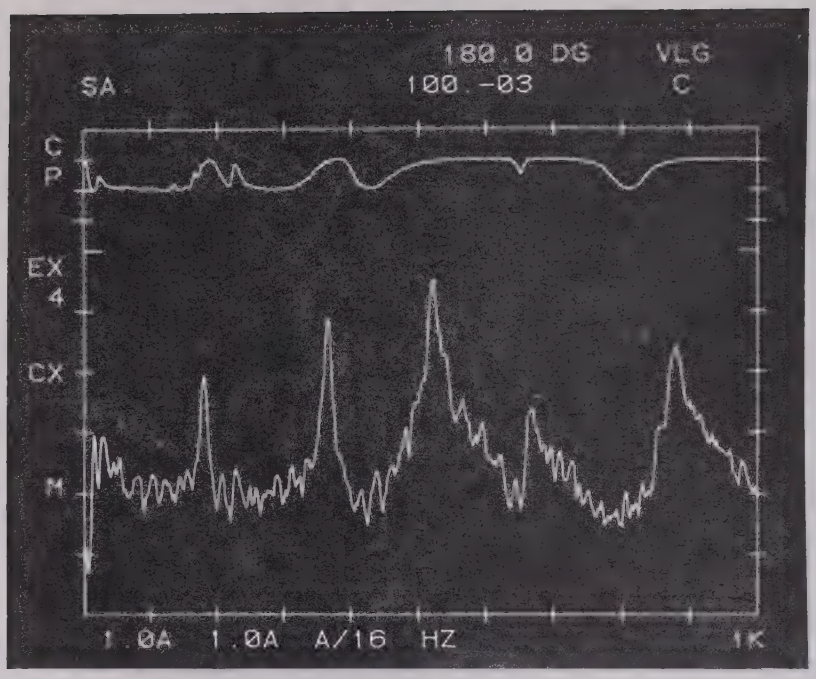



FIGURE S-11.

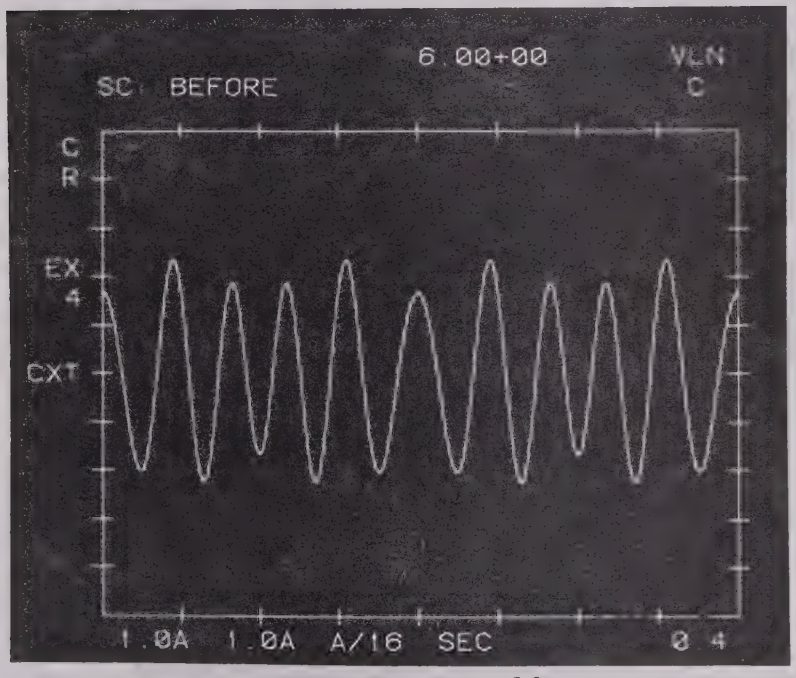



FIGURE S-12.

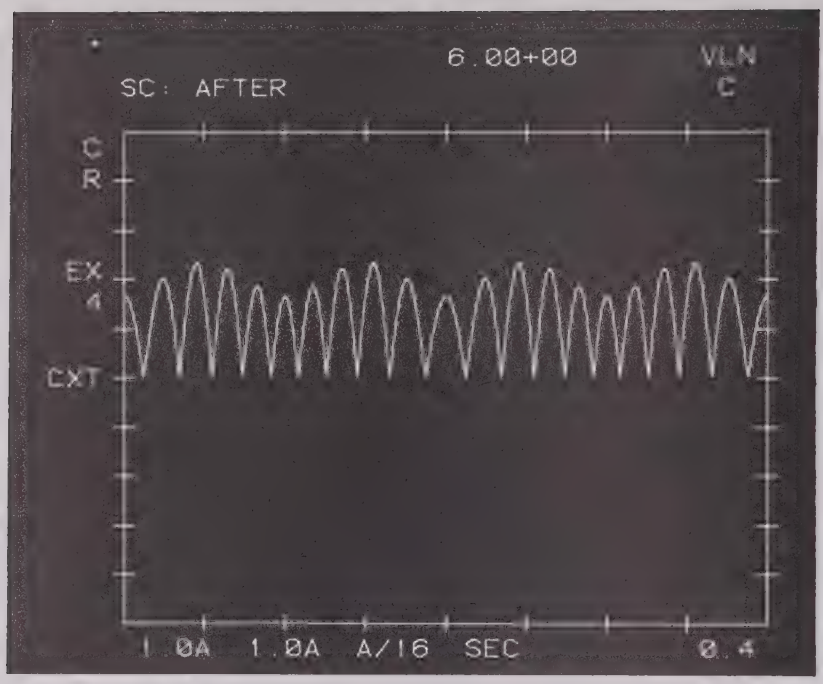



FIGURE S-13.

D. S5[1] - Clears buffer 5 Cross Spectrum Real.
Execution is on a one-shot basis by SHIFT 2 EXC.

E. S6[1] - Clears buffer 6 Cross Spectrum Imaginary.
Execution is on a one-shot basis by SHIFT 2 EXC.

F. Damping

The Damping properties of a resonance are described by an amplification factor, Q. The amplification factor is related to the viscous damping factor, $\zeta$, by the relationship:

$$Q = \frac{1}{2\zeta}$$

where: $\zeta$ = damping ratio

Q may be measured from the frequency response function by several methods (Figure S-14). The 660B implements the following method (Figure S-15):

$$Q = \frac{(f_a/f_b)^2 + 1}{(f_a/f_b)^2 - 1}$$

where: $f_a$ = frequency of +peak in TF real above resonance

$f_b$ = frequency of -peak in TF real below resonance

then: $\text{damping} = \frac{1}{2Q}$

The procedure is as follows (Figure S-16):

1. Set the cursor to the frequency below the resonance:
   1 SET/STORE CUR/LOC

2. Set the cursor to the frequency above the resonance:
   2 SET/STORE CUR/LOC

3. Depress: SHIFT 2 then 9.

The damping factor will be computed and displayed in the upper left corner of the display.

---

[1]S5 and S6 are the only CM commands that modify normal 660B Averager buffers.

FIGURE S-14.

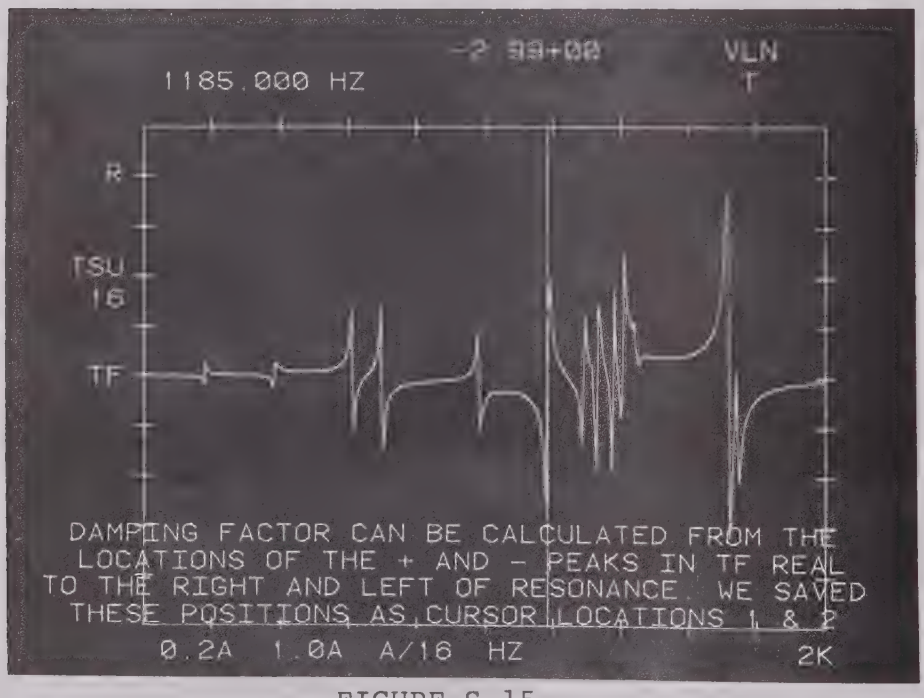



FIGURE S-15.

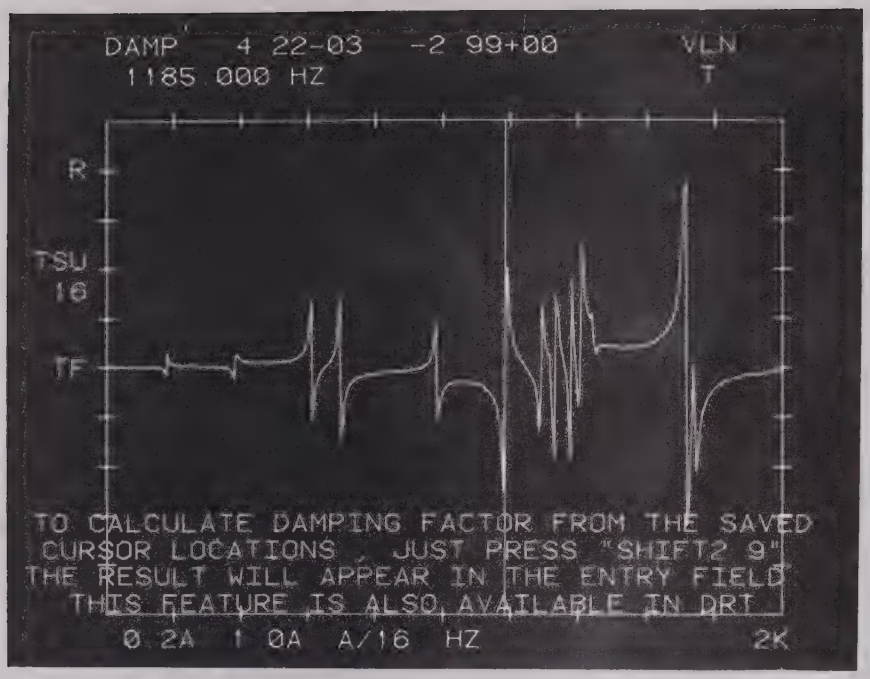

DAMP 4 22-03 -2 99+00 VLN
1185 000 HZ T
R
TSU
16
TF
TO CALCULATE DAMPING FACTOR FROM THE SAVED
CURSOR LOCATIONS , JUST PRESS "SHIFT2 9"
THE RESULT WILL APPEAR IN THE ENTRY FIELD
THIS FEATURE IS ALSO AVAILABLE IN DRT
0 2A 1 0A A/16 HZ 2K

FIGURE S-16.

## S-6. APPENDIX - ERROR CODES

The following error messages may result from the use of Option -8 Complex Math (CM). Errors appear in inverted type in the upper left of the display screen. The action which caused the error does not alter any system parameters. Error messages are grouped according to the pushbutton to which they are associated.

### A. Errors on CM (Complex Math)

| | |
|---|---|
| ONLY IN 1K FFT | Only in 1K FFT (or SIG ENH for synchronous TF). |

### B. Errors on STO C (Store C)

| | |
|---|---|
| ONLY IN 1K FFT | Only in 1K FFT (or SIG ENH for synchronous TF). |
| CAN'T STORE C | Can not scale and store this function as frequency data in C. |

### C. Errors on IFFT

| | |
|---|---|
| ONLY IN VIEW C | Only data in C buffer may be inversed transformed. |
| STORED DATA | Similar error to above: Can not transform data in DMSTORE. |
| N/A IN XPND | Only available in baseband. |
| NOT DURING AVG | If a valid, live equation is being executed (averaged), C can not be transformed to time. |

### D. Errors on EXC (Execute)

| | |
|---|---|
| NON-OPERATIVE | Must be in CM mode. |
| INVALID STRING | Must verify first, then execute. |
| MUST AVERAGE | The equation involves instantaneous data, start the averager to execute |
| CAN'T EXECUTE | The compiled (verified) command string could not be executed. Re-verify. If error persists, run Selftest. |

E. Errors on Damping Factor Calculation

| | |
|---|---|
| SET CUR1<CUR2 | Set Cursor 1 to the left of Cursor 2. |

F. Errors on Data Editing

| | |
|---|---|
| ONLY IN VIEW C | Only data in C can be editted. |
| ENTER VALUE | No number in Entry Field for single point edit. |
| NO INTG-d/dt | Can not edit if displayed data is integrated or differentiated. |
| TURN ON CURSOR | Single point edit requires cursor to be on. |
| MATH ERROR | Over or underflow on calculation of memory address to edit. If error persists, run Selftest. |

G. Errors on VER (Verify)

| | |
|---|---|
| EXIT RECALL | Can not verify while in recall. |
| NO COLON | Equation must be terminated by a colon. |
| UNMATACHED | Parenthesis* |
| NESTED >4 DEEP | Parentheses must not be nested more than four deep*. |
| SYNTAX ERROR | The character marked is not part of the character set.* |
| SEQUENCE ERROR | The character marked is part of the character set, but it is out of place in this position.* |
| SIGN OF EXP? | In a floating point constant, the E must be followed by + or -.* |
| MUST BE DIGIT | Either an exponent must contain two digits, or a complex constant must be #, # not #, buffer.* |
| CANT END HERE | The second source for a two source operator is missing.* |
| +-x/ OPERATOR? | Every equation must contain a two source operation (one of these).* |

*The character in inverse video refers to the exact character in error.

G. Errors on VER (Verify) Con't.

| | |
|---|---|
| OUT OF RANGE | Constant outside the range of floating point format. (absolute value > $10^{38}$) |
| ONE DEC. POINT | A constant can have only one decimal point. |
| 14 CHARS/CONST | This constant has more than 14 characters; the 15th is marked.* |
| BUFFERS FULL | Too many temporary results. The operator producing result for which there is not storage space is marked.* |
| 5 OPTIONS MAX | More than 5 single source operations on one source or result. |
| STRING TOO LONG | The executable version of equation does not fit in the space allocated. |
| NO DATA IN D | Display memory buffer is empty.* |
| PROB DATA IN D | Can not use data in probability format.* |
| 2K DATA IN D | Can not use data from 2K FFT.* |
| OCTAVE IN D | Can not use data in this format.* |
| PHASE IN D | Can not use data in this format.* |
| TIME DATA IN D | This warning flashes by before "VERIFIED" appears. It does not prevent the equation from verifying. |
| UNKNOWN | Unrecognized "special" label.* |
| COMPILER ERROR | This message should not appear. Run Selftest. |

H. System Error Messages Applicable to Option-8

| | |
|---|---|
| N/A IN OCTAVE | This feature not available while Octave is on. |
| OPTION N/A | No code exists to handle this pushbutton or command. |
| BAD STATUS | Internal communication error. Run Selftest. |

*The character in inverse video refers to the exact character in error.

# 660B ADDENDUM

## 660 WITH GC SOFTWARE

The following list represents additional features of all 660Bs equipped with "GC" revision software. These changes effect Option -8 and Option -3.

Option -8 changes include:
- Force/Response Windows (D-1)
- RMS Cursors (D-2)
- Complex Math Specials (D-3)

Option -3 changes include:
- Cross Spectrum Octave (D-4)
- RMS Cursors (D-5)

To determine the software version of the 660B, simply depress (SHIFT 1 and .[decimal point]). A two character letter code will appear in the entry field indicating software revision in this unit.

If a 660B does not have "GC" software and these capabilities are desired, a software update is available. Please consult a local sales representative for cost and delivery date.

## OPTION -8

### D-1. Force and Response (F/R) Time Windows Used With Impact Excitation

Impact testing is a common method of artificially exciting a structure to collect transfer function data. Care must be taken, however, to minimize data contamination caused by measurement noise and spectral leakage. The following sections outline how the force and exponential time windows can be used to reduce measurement error.

A. The "Force" Window

Exciting a structure by impacting it with a hammer is a convenient method of providing an impulsive input. Figure D-1 shows a typical force signal for impact testing.

The impulse signal itself occurs in only a small portion of the time sample used to compute the force channel's Fourier Transform. The remainder of the time sample contains only noise.

The adjustable force window may be used to remove the undesired noise from this signal. Removing the noise from the measurement restores the time sample to a more accurate representation of the actual input force signal. This is particularly useful for DRT or "Zoom" analysis where the sampling periods are long and the noise to signal ratio can be high.

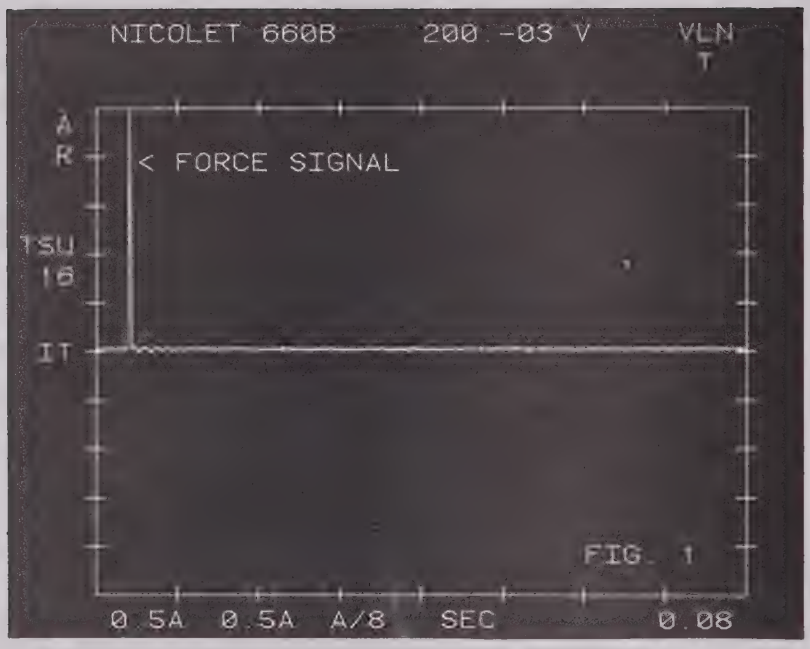

NICOLET 660B
200 -03 V
VLN
T
A
R
< FORCE SIGNAL
TSU
16
IT
FIG. 1
0 5A 0.5A A/8 SEC 0.08

FIGURE D-1

The force window in the 660B is defined by the locations of cursors $C_1$ and $C_2$. Cursor $C_1$ defines the beginning of the force window. All time samples from the beginning of the captured data to $C_1$ will be set to zero. (See Figure D-2.) $C_1$ defines the first non-zero time sample. Cursor $C_2$ defines the last non-zero sample in the window. All data to the right of $C_2$ will be set to zero. Figure D-3 shows the created force window overlapped with a sample impact.

B. The Exponential Windows

Figure D-4 shows a typical response measurement obtained by exciting a structure with an impulsive force (impact testing).

Notice that this signal does not decay to zero in the sample window. This will cause spectral leakage in the computation of its Fourier Transform.

Even under ideal measurement conditions, there will be some background noise present. Since the response signal decays with time, its signal to noise ratio will become poor towards the end of the time window.

Both leakage and noise errors can be reduced by weighting the response signal with an exponential window. The exponential window is applied by multiplying the time data x(t) by an exponential function of the form

$$w(t) = e^{-\alpha t}$$

The response signal which is then Fourier transformed is

$$x_s(t) = w(t) \cdot x(t)$$

The exponential window in the 660B is defined by locations of cursors $C_3$ and $C_4$. (See Figure D-5.) Cursor $C_3$ defines the start of the exponential window. All time samples from the beginning of the captured data (Figure D-3) to $C_3$ will be set to zero. $C_3$ defines the first non-zero time sample. Cursor $C_4$ defines the "time constant" for the window so that at $C_4$ the exponential weighting function has the value

$$w(C_4) = e^{-1}$$

The weighting function is, in terms of cursor positions, defined as

$$w(t) = \exp\left[\frac{-t}{(C_4 - C_3)}\right]$$

where $C_3$ and $C_4$ are defined as time samples between 1 and 1024.

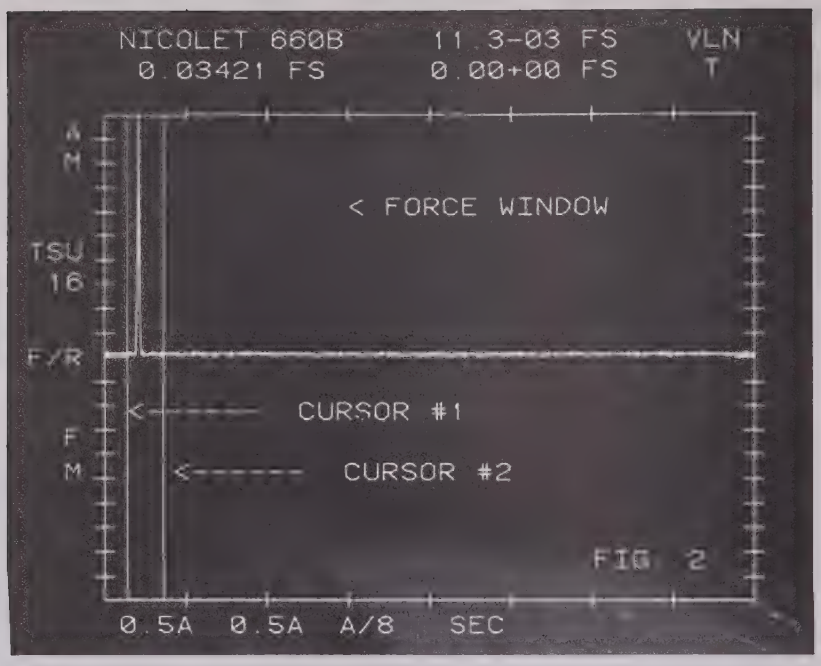



FIGURE D-2

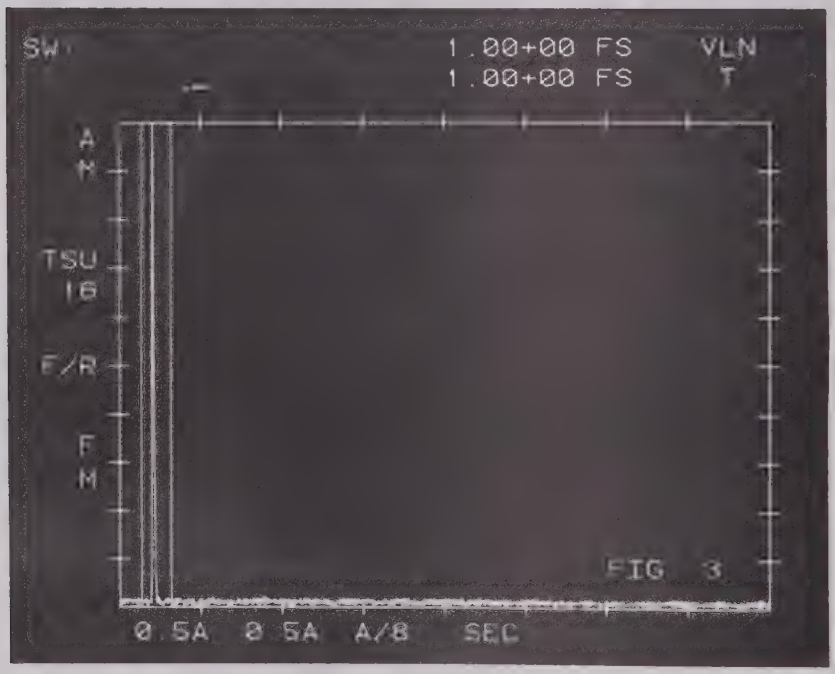



FIGURE D-3

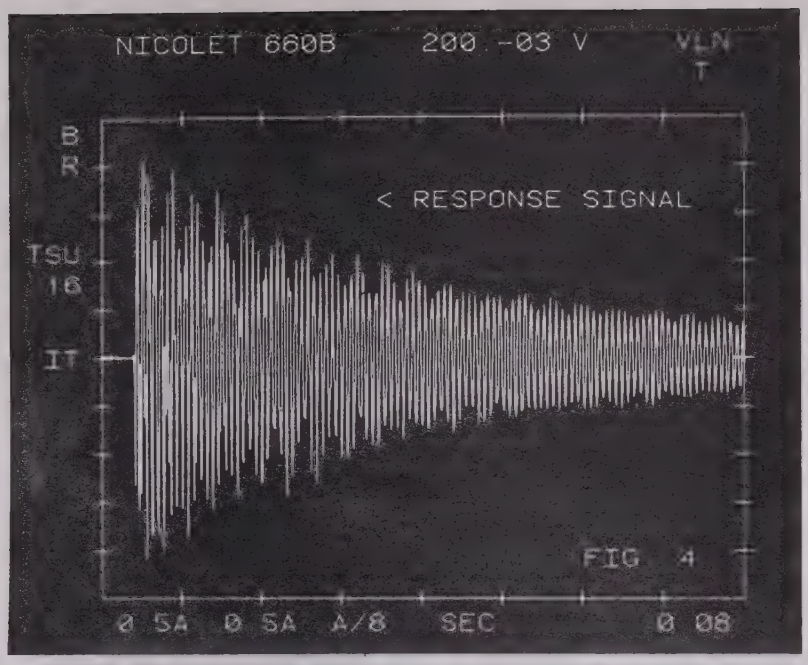



FIGURE D-4

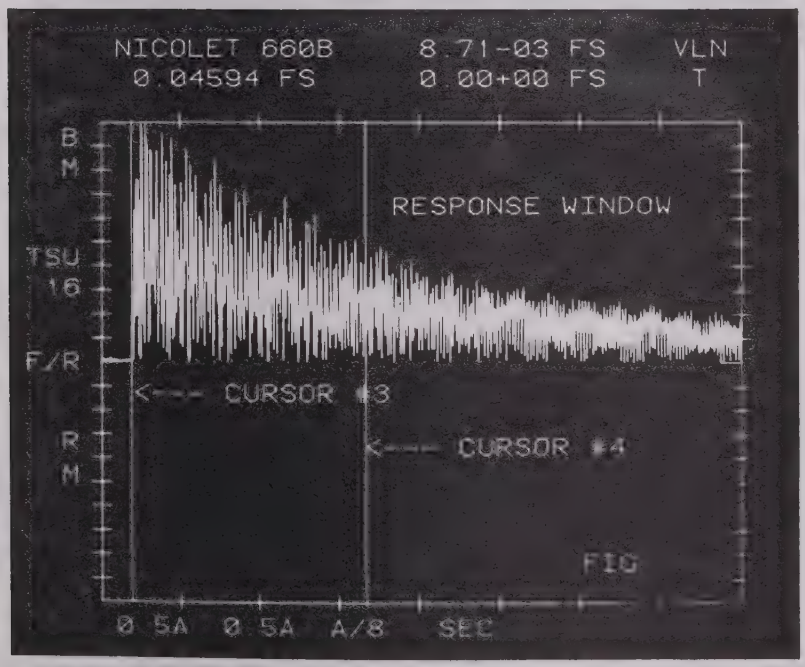



FIGURE D-5

Multiplying the true response signal by an exponential window will distort its Fourier Transform. For transfer function measurements, weighting the response with an exponential window has the effect of adding damping to the measurement. The amount of damping added can be calculated knowing the time constant, $\alpha$ [$\alpha=1/(C_4-C_3)$], which defines a particular window. Figure D-6 shows the created exponential window overlapped with a sample response signal.

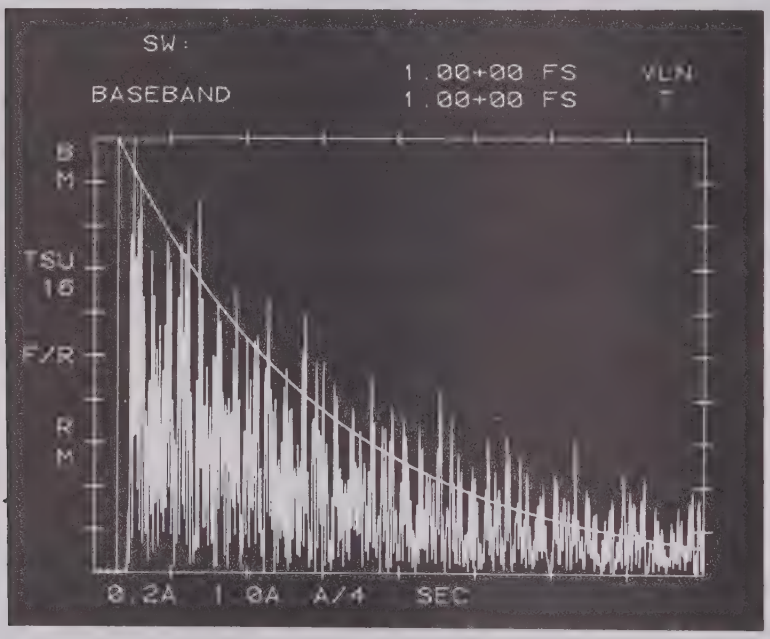



FIGURE D-6

C. Force and Response Windows Operation

The following procedure describes how to enable the 660B F/R windows.

1. Select DUAL 1 K Mode

The F/R windows are an additional feature of the -8 Spectrum Calculation Option. These windows are applied through the use of the Complex Math Special[1] "SW" which is valid only in the DUAL 1 K mode.

---

[1]Refer to Option -8 Section of the 660B Manual, page S-24.

2. Select XPND

If digital range translation (DRT) is required, the desired analysis must be set up before entering the CM (complex math) mode. This is true whenever the XPND mode is desired. Therefore, begin at this step if a change from baseband processing to XPND processing is required, (i.e., exit the CM mode, set up XPND, enter the CM mode).

3. Select CM

Entering CM automatically enables the text field for equation entry.

4. Type Equation "SW:"

Whenever this equation is "verified" and the averager has been started, the created F/R windows will be applied to the input time data of Channels A and B. Once F/R weighting has been applied and the frequency spectrum averaged, it cannot be removed (e.g., TRAN, CONT WEIGHTING). This is not true of the instant spectrum display which is only weighted by the F/R method while the average is running.

5. Depress TEXT

Disable the text mode.

6. Depress VIEW F/R

The display format for the View F/R is a dual-trace time display with the magnitude of a(t) or b(t) as the top trace and either the force or response window respectively as the second trace. In this mode, the time data is always scaled by the largest value defining the top of the trace as one. Therefore, the gain controls have been disabled. The cursor amplitude is displayed as a fraction of the full scale from 0→1.

7. Depress CH A

Channel A time (a(t)) and the force window are now on the display. A sample spectrum should be captured at this time so the force window may be determined accurately. Be sure that the appropriate trigger delays T→A, A→B, and data redundancy (DEF AUX 11) have been set prior to data collection.

8. Set Cursor 1

Move the cursor to the first valid data point of the impulse (force signal). Store Cursor 1 at this point (1, SET STORE, CUR LOC).

9. Set Cursor 2

Move the cursor to the last valid data point of the impulse (force signal). Store Cursor 2 at this point (2, SET STORE, CUR LOC).

10. Depress CH B

Channel B time (b(t)) and the response window are on the display.

11. Set Cursor 3

Move the cursor to the first valid data point of the exponential (response signal). Store Cursor 3 at this point (3, SET STORE, CUR LOC).

Note: Most often, Cursor 3 will be selected to be the same as Cursor 1.

12. Set Cursor 4

Move the cursor to the right of the stored Cursor 3 position. Cursor 4 defines the first time constant delay point (4, SET STORE, CUR LOC).

13. Depress SHIFT 2, VER

During the verification process, the windows are drawn automatically. It is recommended that the created window be verified by comparing the captured sample data. If the windows require modification, reposition the appropriate cursors (1, 2 force; 3, 4 response) and depress SHIFT 2, VER.

Note: SW is a special Complex Math equation. Restrictions about changing average mode, average N, attenuator settings, and EU/V apply. Verification of the equation (SHIFT 2, VER) is required if any of the above are changed.[1]

The analyzer is now set to process data with the F/R windows. Simply depress the desired functions (e.g., power spectrum, transfer function) and start the averager. The analyzer will now process all spectrum data normally with the added benefit of F/R weighting.

---

[1]Refer to Option -8 Section of 660B Manual, page S-13, Part G "Complex Math Scaling."

D. Special Features of F/R Windows

1. Digital Range Translation (XPND Processing)

An additional benefit of enhanced FFT computation is obtained when applying the F/R windows during XPND Processing. Due to the extremely small signal to noise ratios, which are typical during this type of processing, an auto ratio gain is applied prior to FFT processing. This greatly improves the effective dynamic range when impact testing in XPND.

2. Rectangular Windows

The selection of the exponential window may be modified slightly in order to facilitate force window processing only. Specifically, if Cursors 3 and 4 are stored in the same position, the response window will be forced to a rectangular window. The force window is still a function of the stored Cursors 1 and 2.

Note: To take advantage of the improved dynamic range in XPND without the effect of F/R windows, Cursors 1 and 2 should be set to the extreme left and right edge of the display respectively, and Cursors 3 and 4 should be stored in the same position. Thus, the windows will have no effect, but the auto ratio gain will still be applied.

3. Interfacing

Another added feature of the GC Software and F/R windows is the availability of the F/R time windows through the 660B I/O interfaces. This means that custom generated time windows may be used as weighting functions for spectrum processing. Additionally, any other standard time window (Kaiser Bessel, Hamming, etc.) may be inserted through the I/O interfacer and used. (Note: Consult your local sales engineer for information concerning the Option 43-6/HP85A demonstration programs.)

E. Restrictions

A restriction exists upon the use of the C buffer while performing F/R processing. The C buffer is used for storage of the response window and may not be used as a general storage buffer.

If the C buffer is inadvertently destroyed, simply depress "VIEW F/R" and verify the special equation "SW:" and the windows will be recreated.

| SHORT FORM TABLE | | |
|---|---|---|
| 1. Select DUAL 1 K MODE | : | |
| 2. Select XPND | : | If desired. |
| 3. Select CM MODE | : | Text enabled. |
| 4. Type equation "SW:" | : | |
| 5. Depress TEXT | : | Text disabled. |
| 6. Depress VIEW F/R | : | |
| 7. Depress CH A | : | Collect sample of data. |
| 8. Depress 1, SET STORE, CUR LOC | : | Store Cursor 1 at beginning of force signal. |
| 9. Depress 2, SET STORE, CUR LOC | : | Store Cursor 2 at end of force signal. |
| 10. Depress CH B | : | |
| 11. Depress 3, SET STORE, CUR LOC | : | Store Cursor 3 at beginning of response signal. |
| 12. Depress 4, SET STORE, CUR LOC | : | Store Cursor 4 at end of response signal. |
| 13. Depress SHIFT 2, VER | : | Create windows. |

## D-2. RMS Cursors in Complex Math[1]

The ability to compute RMS power between stored cursor positions has been added to the Complex Math storage buffer (C buffer) and Octave Processing. The RMS cursors operate as a normal system with the following definitions.

Complex Math

While viewing C buffer (VIEW C is depressed), if 210 DEF AUX (default) is selected (power function), then

$$\text{RMS CURSORS} = \sum_{\text{Cursor 1}}^{\text{Cursor 2}} C_{MAG}/w$$

If 211 DEF AUX is selected (voltage function)

$$\text{RMS CURSORS} = \sqrt{\sum_{\text{Cursor 1}}^{\text{Cursor 2}} C_{MAG}/w}$$

where $C_{MAG} = \sqrt{C_{REAL}^2 + C_{IMAG}^2}$

$w$ = weighting factor = 1.944 TRAN

1.0 CONT

---

[1]Refer to Section 16 of the 660B Manual, page 11, point 9.

## D-3. Complex Math Specials

The following changes have been made to the CM special funtions.[1]

SA - Places RMS spectrum Channel A into complex buffer CR, and

Places RMS spectrum Channel B into Complex buffer CI.

This function is executed as a live equation (i.e., after every average cycle).

Therefore: $MAG = \sqrt{V_A^2 + V_B^2}$

$$\phi = TAN^{-1} \frac{V_B}{V_A}$$

where $V_A$ = RMS CH A

$V_B$ = RMS CH B

SB - eliminated : same as STO C while viewing RMS spectra CH A, CH B.

ST - A new complex math special which performs a 1024 point multiplication between buffers D and C. This CM special should be used to multiply time data stored in D buffer with time data in the C buffer.

Operation:

1. Store time data in D buffer.
2. Store time data in C buffer.
   (depress IFFT)
3. Execute "ST:"
4. (d(t) * c(t)) → C buffer

---

[1]Refer to Section 24 of the 660B Manual.

## D-4. Cross Spectrum Octave

Reference 660B Manual, page 0-11, Note 1, the limitation of 50 dB dynamic range on cross spectrum octave has been corrected to the full system dynamic range (72 dB).

## D-5. RMS Cursors

While viewing an octave RMS spectrum, RMS cursors perform a summation of (V) voltages. While viewing an octave power spectrum, RMS cursors perform a summation of ($V^2$) power.

# APPENDIX A

## 660 ENTRY FIELD MESSAGES AND ERROR INDICATIONS

(appear in upper left "entry field" in the annotated display)

| MESSAGE | DESCRIPTION |
|---|---|
| NICOLET 660 | Indicates that the instrument has just been turned on. |
| BASEBAND DISP | Indicates that an expansion has just been cleared. |
| PANEL (N) | Indicates the current status of the instrument controls is panel pattern #N. (N is between 1 and 9). |
| CURSOR (N) XXXX | Indicates that #N cursor has been recalled. Address XXXX is the cursor location in "CELL" number, i.e., frequency element in a spectrum or sample increments in a time display. |
| FREQ ABSOLUTE | Indicates tht the frequency reference has just been cleared. |
| DISP F.S. SET | Indicates that display Full Scale has just been set by explicit keyboard entry actuated by a momentary flip of either upper or lower gain switch (any 3 digit number with virtually unlimited exponents). As soon as lever "gain" switch is used again, only "preferred" numbers are employed. |
| ERRORS (reversed type) | OPERATOR HAS TRIED TO PERFORM THE FOLLOWING INCORRECT OPERATION |
| XXXX>YYYY | Enter a number not between the limits XXXX and YYYY. |
| 20 to 160 dB | Enter a display dB range outside of the allowable 20 t0 160 dB limits. |
| 20 dB STEPS | Set a display dB range to a non-integer multiple of 20. |
| NO EXPANDER | Set expansion when frequency expansion option (-2) is not in the instrument. |

| MESSAGE | DESCRIPTION |
|---|---|
| ERRORS (reversed type) | OPERATOR HAS TRIED TO PERFORM THE FOLLOWING INCORRECT OPERATION |
| TF NOT STORED | Equalize without previously storing a transfer function. |
| NO STORED DATA | Compare or equalize without prior storage of data. |
| USE XXXX RANGE | Compare displayed function obtained on a range different from the stored function. |
| USE 1K FFT<br>USE 2K FFT<br>USE SIG ENH<br>USE CORR<br>USE PROB | Compare a function in an operating mode different from stored one. |
| VIEW FREQUENCY | Set a frequency or order reference while viewing a function other than frequency. |
| SET ORD > 0.0 | Set an order reference equal or less than 0.00. |
| VIEW A OR B | Set an integration or differentiation operation or enter a volt-per-engineering unit scale constant while viewing a two channel display. |
| MUST VIEW A | View a channel B function when operating in a mode for which only "A" is available. |
| MUST VIEW B | View a channel A function when operating in a mode for which only "B" is available. |
| TURN ON CURSOR | Perform an operation involving the cursor when it is not turned on. |
| CURSOR LIMITED | Cursor position requested does not fall on display. |
| ONLY 2 TRACES | Compare dual displays (that would have resulted in 4 data traces). Selected a "format" requiring 4 traces. Selected A & B channel requiring 4 traces. |

| MESSAGE | DESCRIPTION |
|---|---|
| ERRORS (Con't.)<br>(reversed type) | OPERATOR HAS TRIED TO PERFORM THE FOLLOWING INCORRECT OPERATION |
| RECALL, MATCH | Compare a displayed function which is not the same as the one stored. |
| OPERATION N/A | Operation not applicable to the system. |
| FORMAT N/A | Display format not available in current panel configuration. |
| FUNCTION N/A | Function not available in current panel configuration. |
| N/A IN XPND | The selection function is not available when the expander is active. |
| EXIT EQL | The equalization mode must be exited before the requested operation can be performed. |

# APPENDIX B

## SCHEMATIC DIAGRAMS

This section of the instruction manual contains the interconnection diagrams, the schematics, and wiring diagrams for the Model 660.

These schematics and diagrams are furnished only for test and maintenance purposes. The circuits are proprietary in nature and should be treated accordingly.

We at NSC continually strive to improve design by adding circuit and component improvements as soon as developed and tested. We reserve the right to make changes at any time in order to provide the best possible product.

There may be differences between these schematics and and the actual circuitry. Please consult the factory if problems arise.

APPLICATION NOTE A

NETWORK SYNTHESIS

Design and testing of filter responses, transfer functions (e.g. control loops, structures) is facilitated through the use of the 660B Spectrum Calculation Option. Specifically, any analog system function, which can be expressed in partial fraction form, may be generated using complex math.

The following is an example of a 4th Order Chebychev Filter with design criteria of 1 dB flatness to .2 PI and 15 dB attenuation to .3 PI.

GIVEN:

$$H_A(S) = \frac{.038286}{(S^2 + .4233S + .1103)(S^2 + .1753S + .3894)}$$

$$= \frac{.038286}{S^4 + .5986S^3 + .5739S^2 + .1842S + .0429} \qquad (1)$$

Equation (1) may be executed using 660B Complex Math and the resulting frequency spectrum (i.e. filter response) may be further manipulated using created, averaged, or live data.

CREATE S (S=Jω) AND STORE IN D BUFFER (Refer to Figure A-1.)

PROCEDURE :

| | | | |
|---|---|---|---|
| 1. | SYS ReSeT | : | Define initial conditions. |
| 2. | 1K BW | : | For cursor readout only. (Note: the Frequency Axis will be normalized to PI (π); 1000 Hz = π ∴ 200 Hz = .2 PI, 300 Hz = .3 PI, etc.) |
| 3. | VIEW C | : | Set up to create Jω. |
| 4. | IMAGinary | : | View IMAGinary part of the Complex Buffer |
| 5. | Cursor ON | : | |
| 6. | 1. SET CUR LOC | : | Position Cursor 1 to start. |

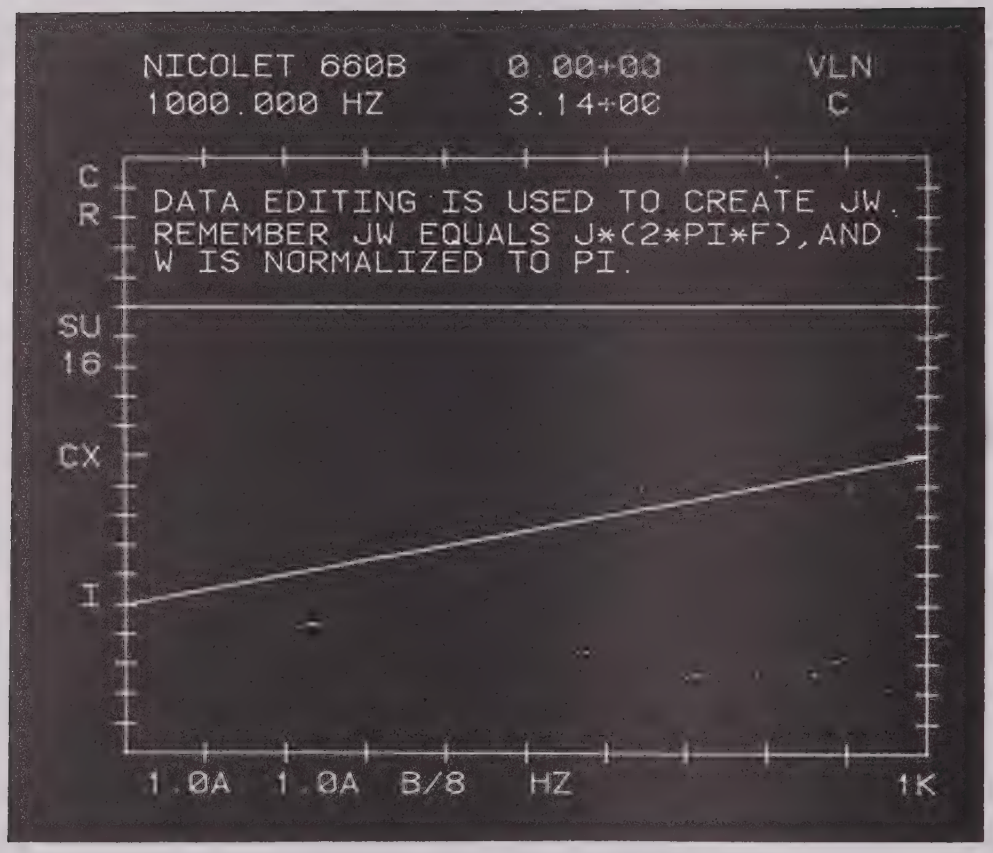

NICOLET 660B
1000.000 HZ
0.00+00
3.14+00
VLN
C
C
R
DATA EDITING IS USED TO CREATE JW.
REMEMBER JW EQUALS J*(2*PI*F), AND
W IS NORMALIZED TO PI.
SU
16
CX
I
1.0A
1.0A
B/8
HZ
1K

FIGURE A-1.

| | | | |
|---|---|---|---|
| 7. | Enter .0078539 | : | Enter $2\pi f_1/2000$ (frequency will be normalized to $\pi$). $f_1 = 2.5$ |
| 8. | SHIFT 2, 5 | : | Insert point. |
| 9. | 1 SET CUR LOC | : | STOre Cursor 1 position. |
| 10. | 400. SET CUR LOC | : | Move cursor to END. |
| 11. | Enter 3.14159 | : | Enter $2\pi f_2/2f_2$ (2)(3.1415)(1000)/2000. |
| 12. | SHIFT 2, 5 | : | |
| 13. | SET/STORE | : | |
| 14. | Flick Upper GAIN Control | : | Scale Display. |
| 15. | 2 SET CUR LOC | : | STOre Cursor 2 position. |
| 16. | SHIFT 2, 6 | : | Create Spectrum. |
| 17. | STO D | : | Place the $j\omega$ Spectrum (i.e. the Laplace Operator S) in "D" Buffer. |

CONVERT NETWORK EQUATION INTO COMPLEX MATH EQUATIONS (Refer to FIGURE A-2). EQUATION (1) WILL BE BROKEN INTO TWO UNIQUE PARTS.

| | | | |
|---|---|---|---|
| 18. | Enter CM | : | TEXT Enabled, CLEAR, 2 Buffer. |
| 19. | Depress TEXT 2 | : | Enable the Second Text String. |
| 20. | Type the following equation using the Text Entry Key Pad (Part 1) | : | (D x D x D x D + .5986, 0 x D x D x D) + .5739, 0 x D x D : |
| 21. | Depress TEXT 3 | : | Enable the Third Text String. |
| 22. | Type the following equation using the Text Key Entry Pad (Part 2) | : | .038286, 0/(C + .1842, 0 x D + .0429, 0) : where C = equation from Part 1. |

0.00+00
VLN
1000.000 HZ
0.00+00
C
C
R
(D*D*D*D+.5986,0*D*D*D+.5739,0*D*D
.038286,0/(C+.1842,0*D+.0429,0):
SU
16
CX
I
1.0A
1.0A
B/8
HZ
1K

FIGURE A-2.

CREATE FREQUENCY RESPONSE (Refer to Figure A-3).

| | | |
|---|---|---|
| 23. | Depress TEXT 2 | : |
| 24. | SHIFT 1, 5 | : Copy TEXT 2 -> TEXT 1. |
| 25. | SHIFT 2, VER | : Verify equation. |
| 26. | SHIFT 2, EXC | : Execute equation. |
| 27. | Depress TEXT | : |
| 28. | Depress TEXT 3 | : |
| 29. | SHIFT 1, 5 | : Copy TEXT 3 -> TEXT 1. |
| 30. | SHIFT 2, VER | : Verify. |
| 31. | SHIFT 2, EXC | : Execute. |

THE RESULT IS IN C BUFFER.

| | | |
|---|---|---|
| 32. | Depress ϕ/MAG | : View Transfer Function. |

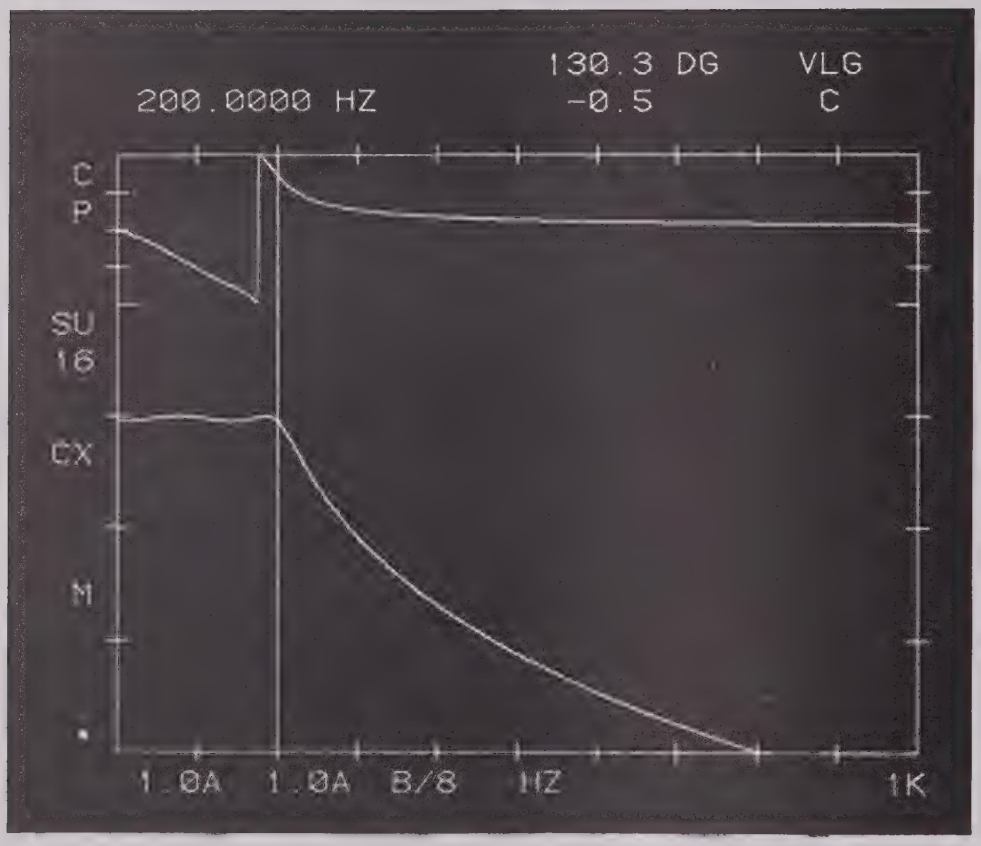


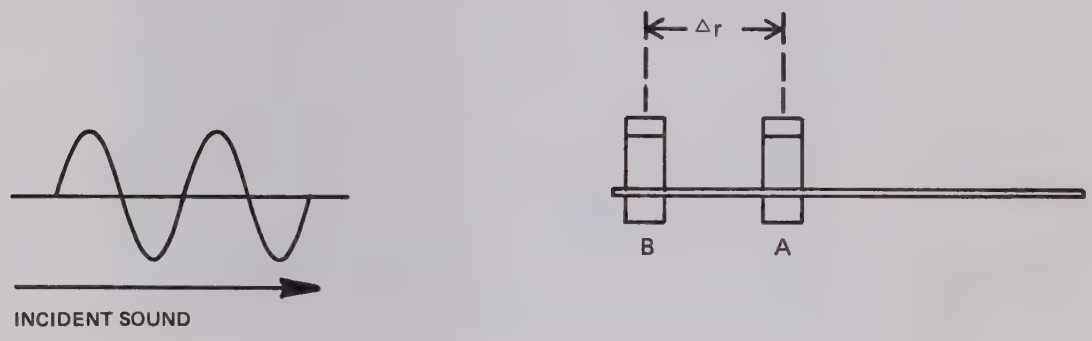

FIGURE A-3.

APPLICATION NOTE B

ACOUSTIC INTENSITY

This article is concerned with the application of the two microphone, cross spectral method for computing sound intensities. It is not intended as a theoretical treatise, but rather as an implementation procedure for the 660B.

Acoustic Intensity at any point in a sound field can be found by measuring the Cross Spectrum ($G_{AB}$) between the pressure at Microphone A and the pressure at Microphone B (See Figure B-1).




(NOTE: Microphone A is at a great distance from the sound source.)

FIGURE B-1

Acoustic Intensity $I(\omega)$ as calculated by the Cross Spectral Method is defined as follows:

$$I(\omega) = \frac{I_m[G_{AB}]}{\rho \Delta r \omega}$$

where: $I(\omega)$ = Acoustic Intensity

$I_m[G_{AB}]$ = Imaginary Part of the Cross Spectrum (Quadrature Spectrum)

$\Delta r$ = The Microphone Separation (Measured Center-to-Center)

$\rho$ = Density of Air

$\omega$ = Frequency Radians/Sec

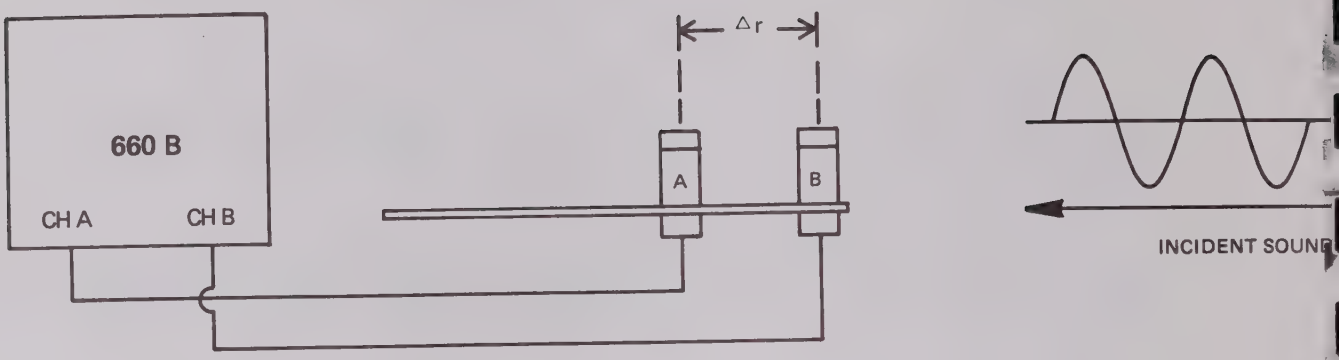



FIGURE B-2

Figure B-2 shows the attachment of the microphone probe.[1]

PROCEDURE

** Construct Linear Relationship "ρ Δr ω" **
(Refer to Figure B-3.)

EX) Assume: $\Delta r$ = .3 inches = .025 feet

$\rho$ = .06 $Lb_m/ft^3$

$\omega$ = $2\pi f$ (f Depends on Analysis Range)

BW = 2 KHZ (Analysis Range)

| | | | |
|---|---|---|---|
| 1. | SYS ReSeT | : | Define Initial Conditions. |
| 2. | Enter CM | : | Complex Math and Text are enabled. |
| 3. | Exit TEXT | : | |

[1]Phase matched and calibrated microphones are essential for reliable intensity measurements. Amplitude and phase correction techniques are discussed in the literature and will be omitted here for clarity.

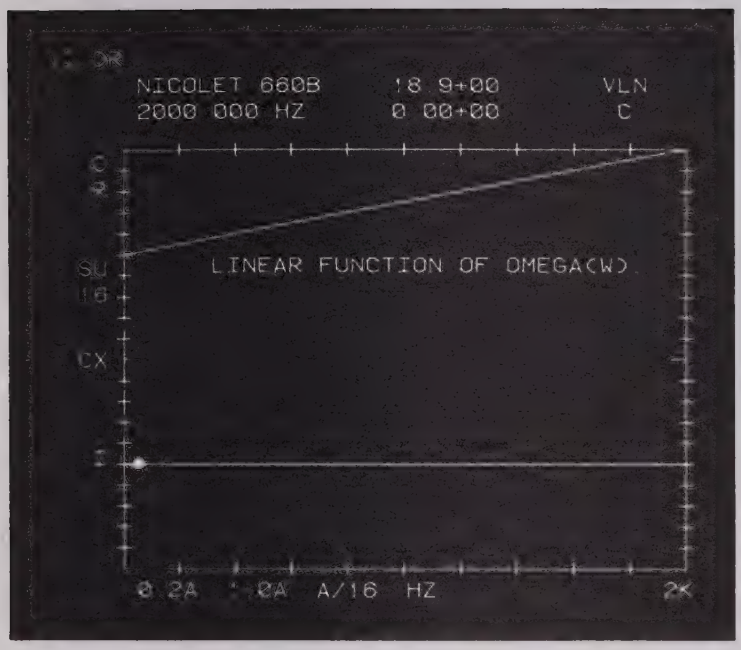

NICOLET 660B
2000 000 HZ
18 9+00
0 00+00
VLN
C
LINEAR FUNCTION OF OMEGA(W)
0 2A
2K

FIGURE B-3

| | | | |
|---|---|---|---|
| 4. | Depress VIEW C | : | Set up to create ω function |
| 5. | Depress REAL | : | View REAL part of Complex Buffer C |
| 6. | Cursor ON | : | |
| 7. | 1. SET CURSOR | : | Position Cursor to Cell 1. |
| 8. | Enter .04712 | : | $\rho\Delta r 2\pi f_1 = (.06)(.025)(6.283)(5)$ |
| 9. | SHIFT 2, 5 | : | Create First Point. |
| 10. | 1 SET CURSOR | : | Store Cursor # 1. |
| 11. | 400. SET CURSOR | : | Position Cursor to Cell 400. |
| 12. | Enter 18.8495 | : | $\rho\Delta r 2\pi f_2 = (.06)(.025)(6.283)(2000)$ |
| 13. | SHIFT 2, 5 | : | Create Last Point. |
| 14. | 2 SET CURSOR | : | Store Cursor # 2. |
| 15. | SHIFT 2, 6 | : | Create function. |
| 16. | STO D | : | Save Function in D Buffer. |

*** Enter Intensity Equation***

| | | | |
|---|---|---|---|
| 17. | Enter TEXT | : | TEXT 1 field enabled. |
| 18. | Enter CM Equation | | |
| | "VI/DR:" | : | Used to calculate the Intensity Spectrum.[2] |
| 19. | SHIFT 2, VER | : | Verify the Equation and Exit Text Mode. |

** Intensity Calculation ** (Refer to Figures B-4, and B-5.)

| | | | |
|---|---|---|---|
| 20. | Set Up 660B | : | AVG N<br>Attenuators<br>Calibration Microphone A - (V/EU) "psf"<br>Calibration Microphone B - (V/EU) "psf" |
| 21. | START AVERAGER | : | |

---

[2]Appropriate scaling will need to be applied based on units desired (example: $psf^2$).

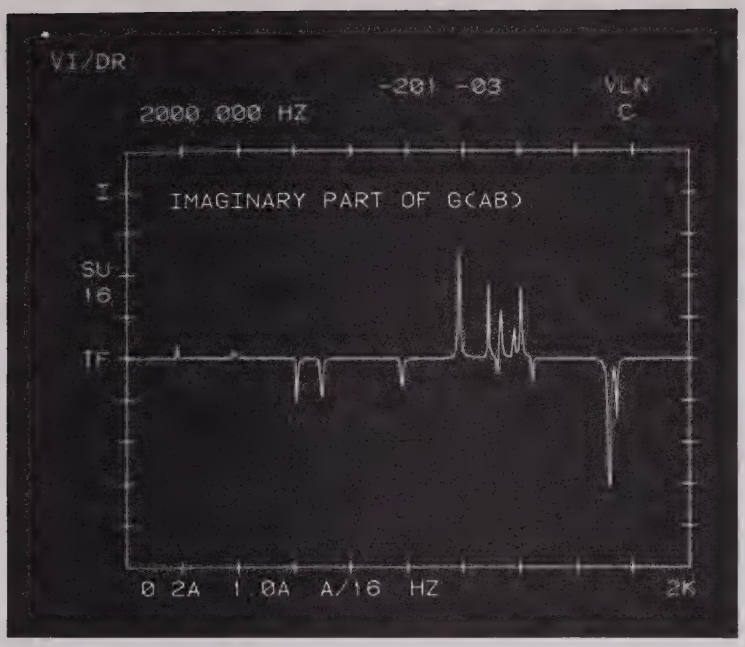



FIGURE B-4

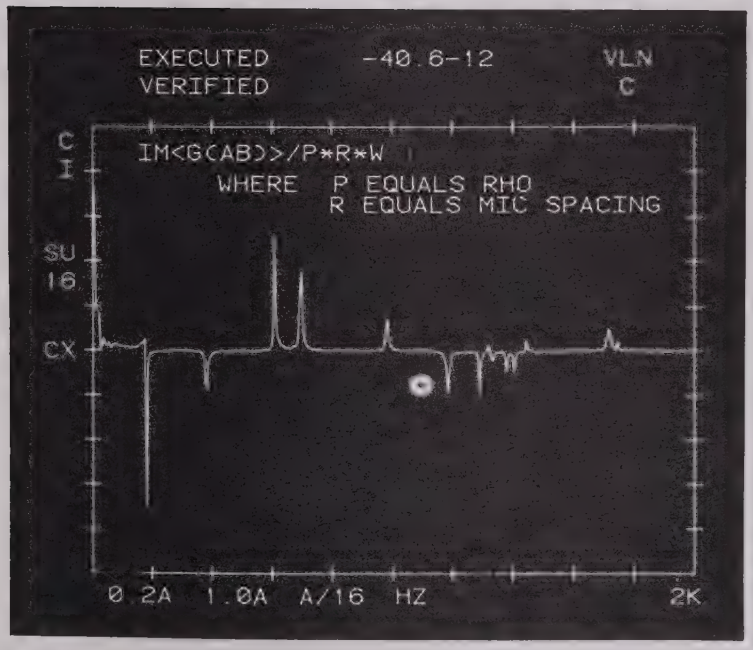



FIGURE B-5

When the Averager Completes:

| | | |
|---|---|---|
| 22. | SHIFT 2, VER | : This step is required only if scale factors from step 18 are changed. |
| 23. | SHIFT 2, EXC | : Execution. |
| 24. | VIEW C | : Buffer CI contains the intensity spectrum. |

Note: For continued measurements, only steps 21 and 23 need to be repeated.

References:

Chung, J.Y., Pope, J., and Feldmeier, D.A., Application of Acoustic Intensity Measurement to Engine Noise Evaluation.

COMPUTING ACOUSTIC INTENSITY ACCORDING TO THE FORMULA

$$Ir = \text{Imag}\ \{[G_{12} \cdot G_{12}^{s}]^{1/2}\ \} /(\rho\ \Delta r\ \omega |H_1||H_2|)$$

Set up (done once in advance):

1. If your microphones are "flat" over the frequency range of interest, skip to Step 6.

2. Collect calibration transfer function for first microphone. Store TF in "D".

3. Collect calibration TF for second microphone.

4. Execute "DM x TM:" C now contains $|H_1| \cdot |H_2|$.

5. View C, press STO D to save $|H_1| \cdot |H_2|$.

6. Exit and re-enter CM to clear "C". Now the the function $\omega$ will be created.

7. VIEW C, REAL.

8. Move the CURSOR to Cell 1.

9. Press "1 SET CUR LOC" to remember this location.

10. Enter the value of $\omega$ ($=2\pi f$) at this point and press "SHIFT 2, 5" to insert this value.

11. Move the CURSOR to Cell 400.

12. Press "2 SET CUR LOC".

13. Enter the value of $\omega$ ($=2\pi f$) at this point and press "SHIFT 2, 5".

14. Press "SHIFT 2, 6" to draw $\omega$.

15. If you performed steps 2-5, execute "D x C". so that C contains $\omega |H_1| \cdot |H_2|$.

16. View C and press STO D.

Actual Execution:

Let us assume that $\rho$ = density of air = .06 $Lb_m/ft^3$ and $\Delta r$ = microphone spacing = .025 ft.

17) Collect $G_{12}$

18) View Cross SPEC and press "STO C".

19) Collect $G_{12}^{s}$.

20) Verify and execute the following two equations:

a) $\sqrt{\ }$(V x C): $C = (G_{12} \times G_{12}^{s})^{1/2}$

b) CI/(.06 x DR x .025): CI = Acoustic Intensity

Note: Steps 17-20 can be repeated as often as is desired.

APPLICATION NOTE C

SYNTHETIC INTEGRATION/DIFFERENTIATION

Synthetic integration or differentiation (i.e., multiplication by $1/j\omega$, $j\omega$) may be performed upon live, static or created data. This allows dynamic viewing of acceleration velocity or displacement frequency waveforms. In addtion, the time domain waveform of the resultant Frequency Spectrum may be viewed through the IFFT (Inverse FFT) control. The following procedure illustrates how this can be done with the 660B Complex Math Option.

A. CREATE $j\omega$ AND STORE IN D BUFFER (Refer to Figure C-1).

PROCEDURE:

| | | | |
|---|---|---|---|
| 1. | SYS ReSeT | : | Initialize 660B. |
| | A. 10kHz BW | : | |
| | B. TRAN | : | Select Transient Averaging |
| 2. | View C | : | |
| 3. | IMAG | : | Set up to create $j\omega$ (View CI). |
| 4. | CURSOR ON | : | |
| 5. | 1. SET CUR LOC | : | Position CURSOR to START. |
| 6. | Enter 157.07 | : | 2 * 3.141 * 25 ($2\pi f$, assume 10 K Bandwidth). |
| 7. | SHIFT 2, 5 | : | |
| 8. | 1 SET CUR LOC | : | Store CURSOR 1. |
| 9. | 400. SET CUR LOC | : | Move CURSOR to end. |
| 10. | Enter 62831.8 | : | 2 * 3.141 * 10000. |
| 11. | SHIFT 2, 5 | : | |
| | A. SET STORE | : | |
| | B. Flick Upper GAIN Control | : | Scale Display |
| 12. | 2 SET CUR LOC | : | STOre CURSOR 2. |
| 13. | SHIFT 2, 6 | : | Create $j\omega$ Spectrum. |

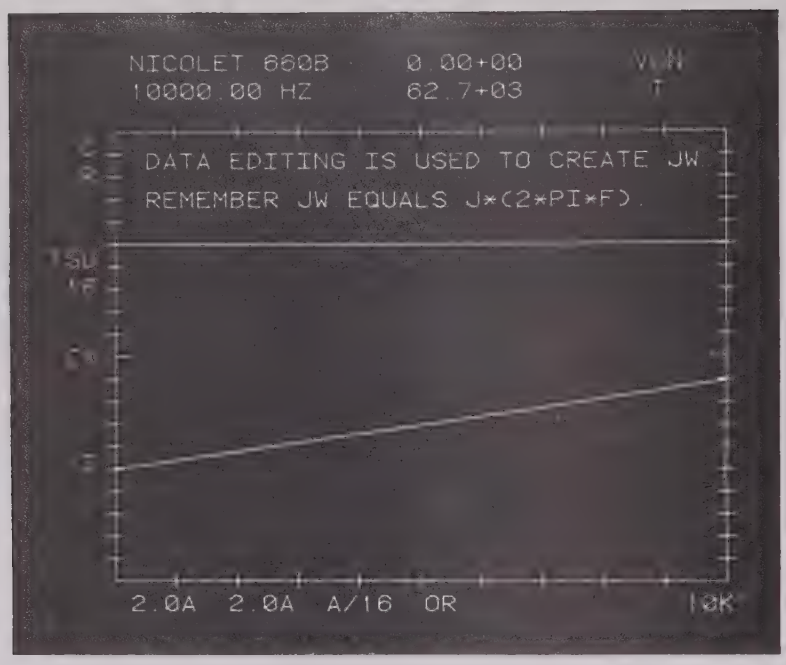



FIGURE C-1.

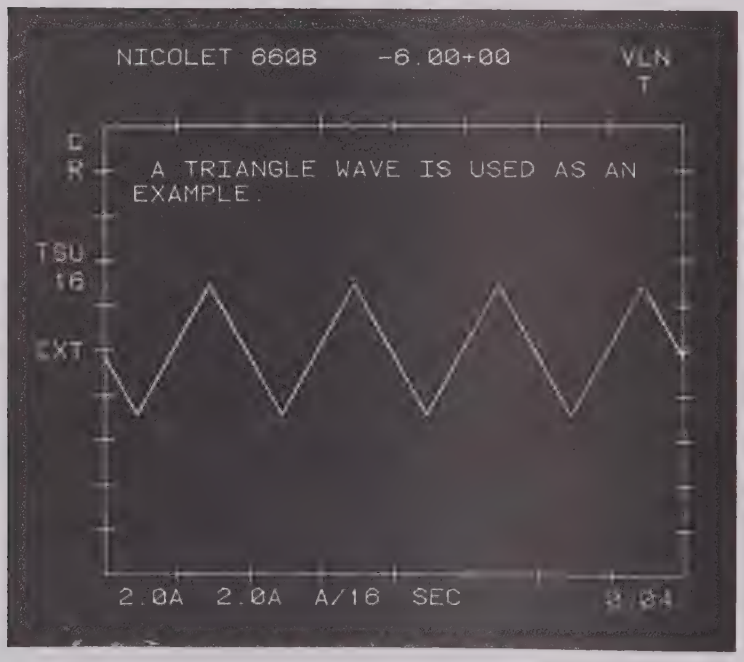



FIGURE C-2.

14. Depress STO D : Save $j\omega$.

The following procedure is for static or created data. (In this example, a signal generator was used to create a triangle wave.)

A. Exit VIEW C :

15. VIEW CHannel A : Refer to Figure C-2.

16. Depress CM :

17. STOre C : Channel A Time data is stored in C. (Note: Time data will be stored as Frequency.)

18. VIEW C : View Frequency.

A. Enter 211 SET STORE DEF AUX : Scale Display

19. Enter "C * D" : Differentiation. (Note: C/D = Integration.)

20. SHIFT 2, VER : Verify.

21. SHIFT 2, EXC : Execute.

22. Depress IFFT : Refer to Figure C-3 (Pulse).

23. Depress IFFT : Return to Frequency.

24. SHIFT 2, EXC : Double Differentiation.

25. Depress IFFT : Refer to Figure C-4 (Impulse).

The following procedure is for live data.

15. Depress CM :

16. Enter "A * D" : Instant $\frac{dA}{d\omega}$

Note: $\frac{d^2A}{d\omega^2} = A * D * D$

17. SHIFT 2, VER : Set Averager type and Averager N before verification.

18. VIEW C : View Frequency.

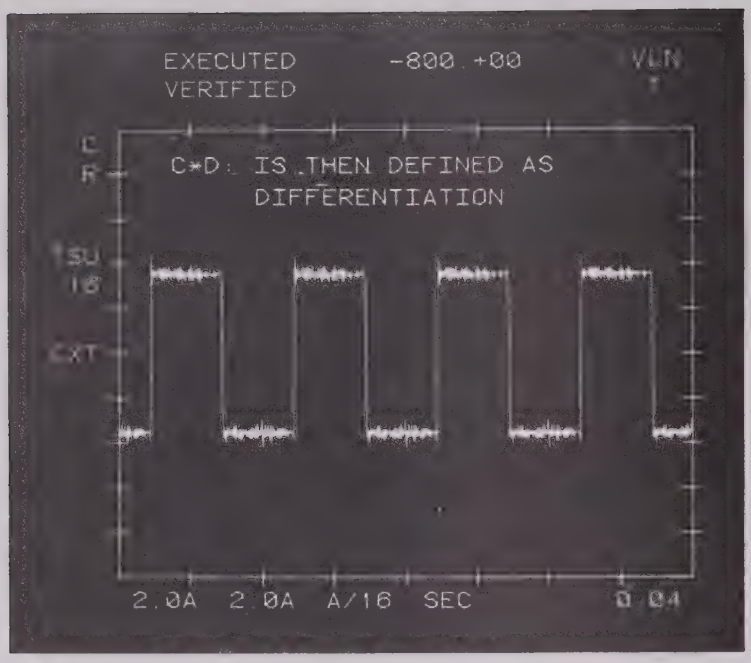



FIGURE C-3.

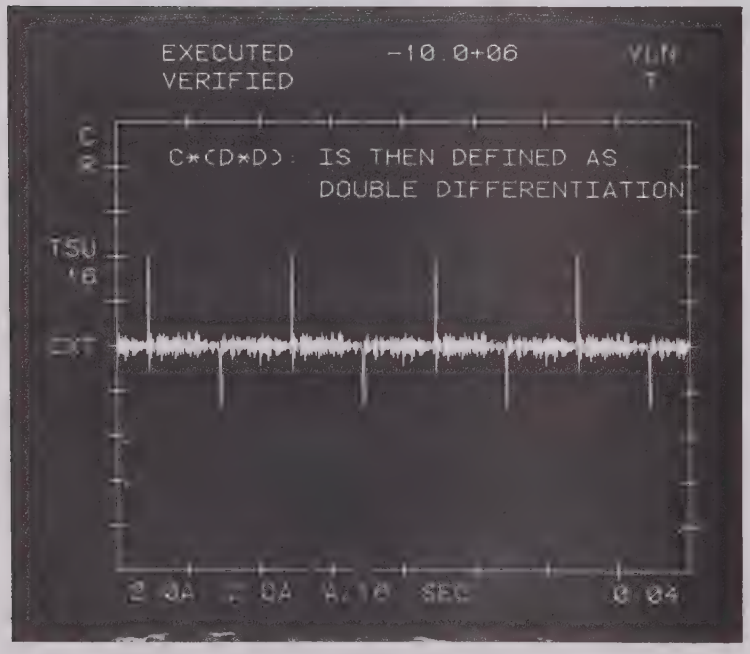



FIGURE C-4.

19. START : Start Averager. The resultant frequency waveform may be viewed dynamically.

Note: When the Averager completes, depress IFFT to view Time.

APPLICATION NOTE D

ENVELOPE DETECTION

The process of separating a baseband or modulated signal from a carrier is called demodulation, or detection. Detection is necessary when the information to be received is carried by a modulating signal.

Envelope detection is a common form of detection and, as the name implies, the output of the detector represents the envelope of the incoming High Frequency (HF) signal.

The procedure is to pass the HF signal through a non-linear device and low pass filter. (Refer to Figure D-1.)

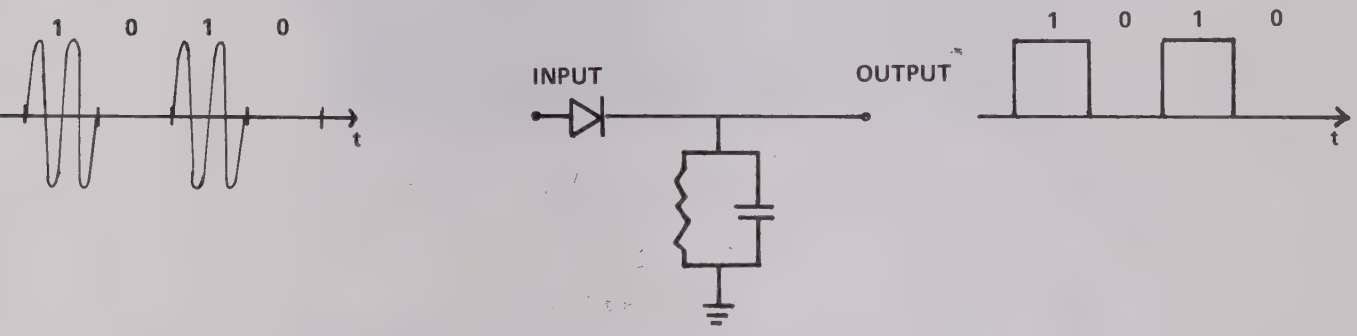



FIGURE D-1
(Envelope Detector)

By performing a full-wave rectification ($\sqrt{v_t^2}$) and low pass filtering, envelope detection may be performed using the 660B Complex Math Option.

A. FULL-WAVE RECTIFICATION

PROCEDURE:

** Store time waveform in Complex Buffer C **
When the data source is the power spectrum or cross spectrum buffers, simply display the data and depress STO C.

1. Display Frequency Data : Channel A or Channel B or Cross Spectra.

2. Depress STO C :

   A. Enter 211 SET STORE DEF AUX : Scale Display

3. Depress VIEW C :

4. Depress IFFT : View time wave form.
If the data is the result of a Complex Math operation,

1. Depress VIEW C : Data already in C buffer.

2. Depress IFFT : View Time waveform.

In this example, an AM modulated sine wave as created using the -8 Option Editing feature:

1. SYS ReSeT :

2. Depress CM : Text Enabled.

3. Enter SC: : Complex Math special for absolute value.

4. Exit TEXT :

5. Depress VIEW C :

(Refer to Figure D-2 which shows real part of an inserted complex frequency spectrum.)

6. Depress REAL :

7. 50. SET CUR LOC : Define fc (Carry Frequency).

8. 10 SHIFT 2, 5 : Define Amplitude of fc.

9. 48. SET CUR LOC : Move CURSOR to LSB (lower side band).

10. 2 SHIFT 2, 5 :

11. 52. SET CUR LOC : Move CURSOR to USB (upper side band).

12. 2 SHIFT 2, 5 : Refer to Figure D-2.

13. Depress IFFT : View Time waveform.
(Refer to Figure D-3.)

A. Enter 30 SET STORE :

B. Flick Upper GAIN Control: Scale Display

14. SHIFT 2, VER :

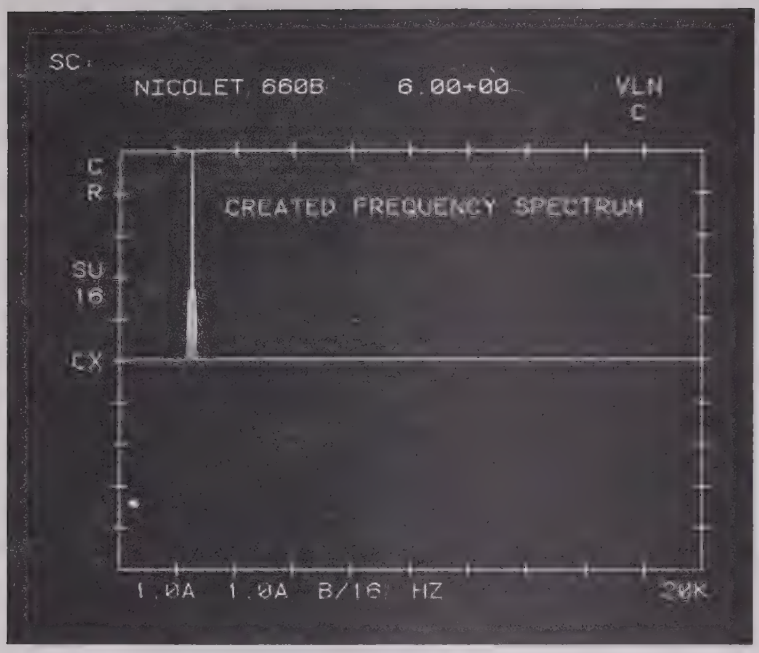



FIGURE D-2

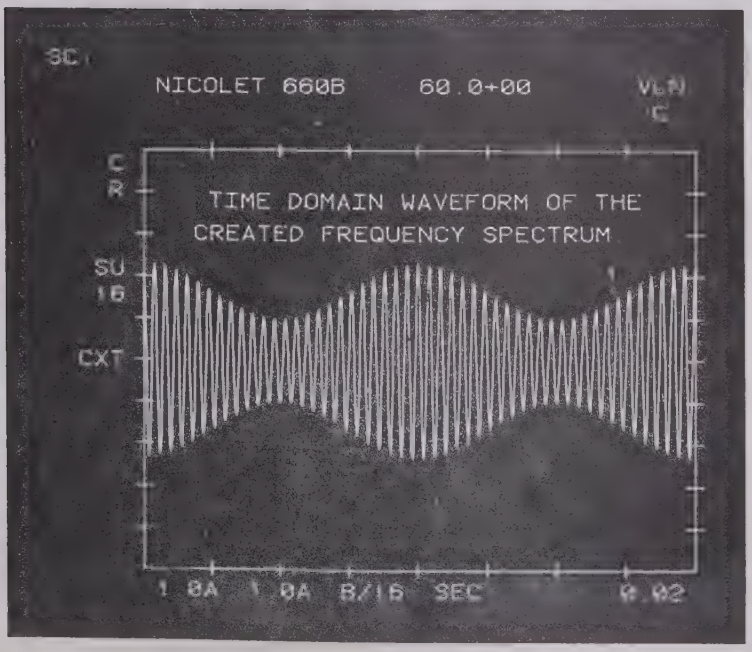



FIGURE D-3

15. SHIFT 2, EXC : Rectified Time. (Refer to Figure D-4.)

B. LOW PASS FILTERING

16. Depress IFFT : Return to Frequency.

Low Pass Filtering may take the form of multiplication with a stored or created frequency response or, as in this example, data editing.

17. 10. SET CUR LOC : Define low pass cutoff.

18. 1 SET CUR LOC :

19. 0 SHIFT 2, 5 :

20. 400. SET CUR LOC : Define upper cutoff.

21. 2 SET CUR LOC :

22. 0 SHIFT 2, 5 :

23. SHIFT 2, 6 : Filtered data. (Refer to Figure D-5.)

24. Depress IFFT : View envelope. (Refer to Figure D-6.)

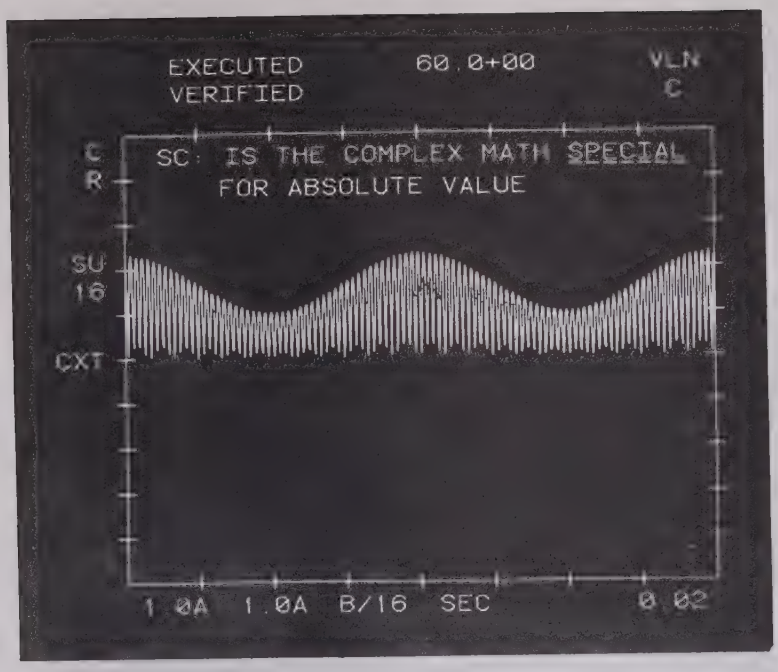



FIGURE D-4

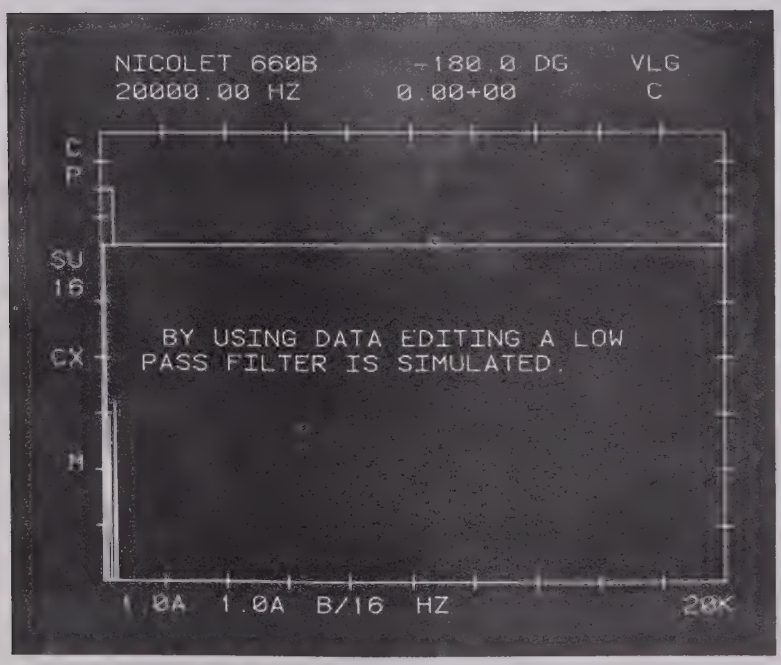



FIGURE D-5

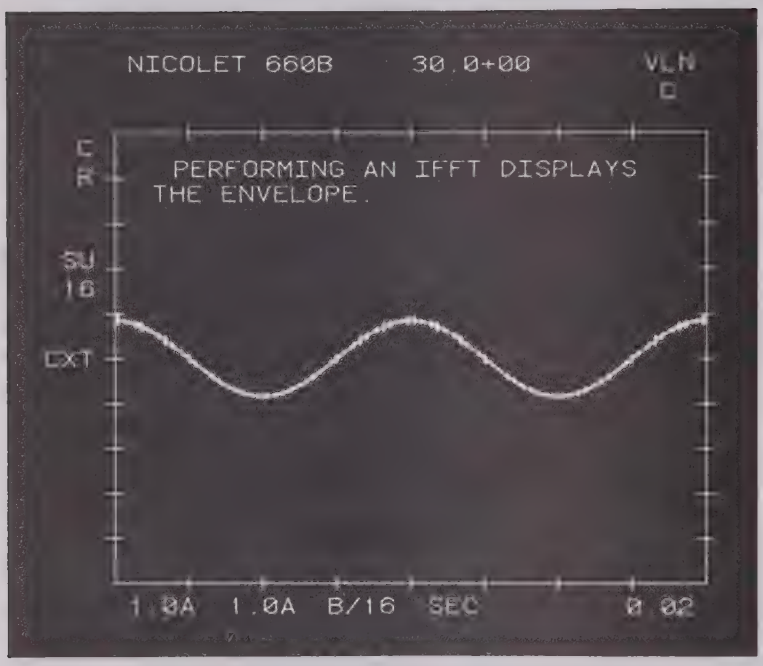

NICOLET 660B
30.0+00
VLN
C
C
R
PERFORMING AN IFFT DISPLAYS
THE ENVELOPE.
SU
16
EXT
1.0A
1.0A
B/16
SEC
0.02

FIGURE D-6

# APPLICATION NOTE E

## HOW TO DO NON-DESTRUCTIVE TESTING WITHOUT DESTROYING ANYTHING

### E-1. INTRODUCTION

Very often, a manufacturer of heavy equipment must submit his product to a non-destructive (although this may not be the result) test to satisfy a customer that the equipment meets certain environmental criteria. Two classic examples of such testing are Navy Shock Tests and Seismic Testing for equipment to be used in nuclear power plants. These tests can end in a machine failure, forcing a redesign of components, pattern changes, and new machining techniques which are quite costly and time-consuming to the manufacturer.

If there were some way to test the machine in the early prototype stage without risking a series of catastrophic failures, severe environmental operating conditions would be much less painful to the manufacturer. The following paper will indicate how this noble goal can be achieved.

### E-2. BASIC ASSUMPTIONS

Two basic asumptions must be made in the proposed method. One is system linearity. The other is a knowledge of the excitation to which the machine is to be subject.

#### A. System Linearity

The assumption of system linearity must be made because the method requires that the transfer function of the system (output motion/input force) does not change with the increase of input force. This is not a very restrictive assumption for a machine capable of passing the proposed test.

If the machine is not to fail due to the specified input forces, it must be designed such that the rotating components do not rub under load - one possible non-linearity, therefore, cannot exist by definition.

To pass an environmental test of the type discussed here, the machine may not undergo plastic deformation. Therefore, Hook's Law, $\delta = E\varepsilon$ , must apply during the application of the load. Hook's Law is linear.

Non-linear hysteretic effects, such as the sliding of a shaft sleeve relative to the shaft,obviously may not be permitted to occur.

B. Excitation Characteristics

It is necessary to know the characteristics of the excitation to which the machine will be subject during the acceptance testing.

One example is the seismic specification shown in Figure E-1. This sort of specification is derived experimentally from past earthquakes. The acceleration levels shown should be assumed to act on the mounting pads of the machine base.

A second type of excitation is imparted during a Navy shock test. In this type of test, the machine under evaluation is mounted on a test bed and a hammer of specified weight is lifted to a specified height and released, hitting the test bed from below. This is seen schematically in Figure E-2. Since the impulse wave form is not specified, its nature must be determined by running a test on a mass equal to that of the machine of interest. A force gauge or accelerometer at the mounting pad should be used to determine the shape of the shock wave into the machine.

## E-3. PREDICTION OF MACHINE CHARACTERISTICS

Given the sort of excitation discussed above, it should be obvious that the two possible reasons for failure during this type of test are the inability of various components to handle static loads in all directions and amplified loading levels due to component resonances. As the static loading problem can be handled with very simple stress calculations, the major risk of machine failure will result from fatigue, excessive motion, or excessive forces due to component resonances. The following describes a method for locating these problems before the embarrassment and cost of component destruction during a non-destructive test take place.

A. Obtain the Transfer Functions

The tranfer function of a structure is, in simple terms, a display of output response divided by input excitation vs. frequency. A typical display can be in the form of a Bode diagram, a Nyquist diagram, or plots of real and imaginary components vs. frequency. (Refer to Figure E-3.)

This paper will use Bode plots which display the values

$$\text{Phase} = \tan^{-1} \frac{\text{TF IMAG}}{\text{TF REAL}}$$

$$\text{Magnitude} = [(\text{TF REAL})^2 + (\text{TF IMAG})^2]^{1/2}$$

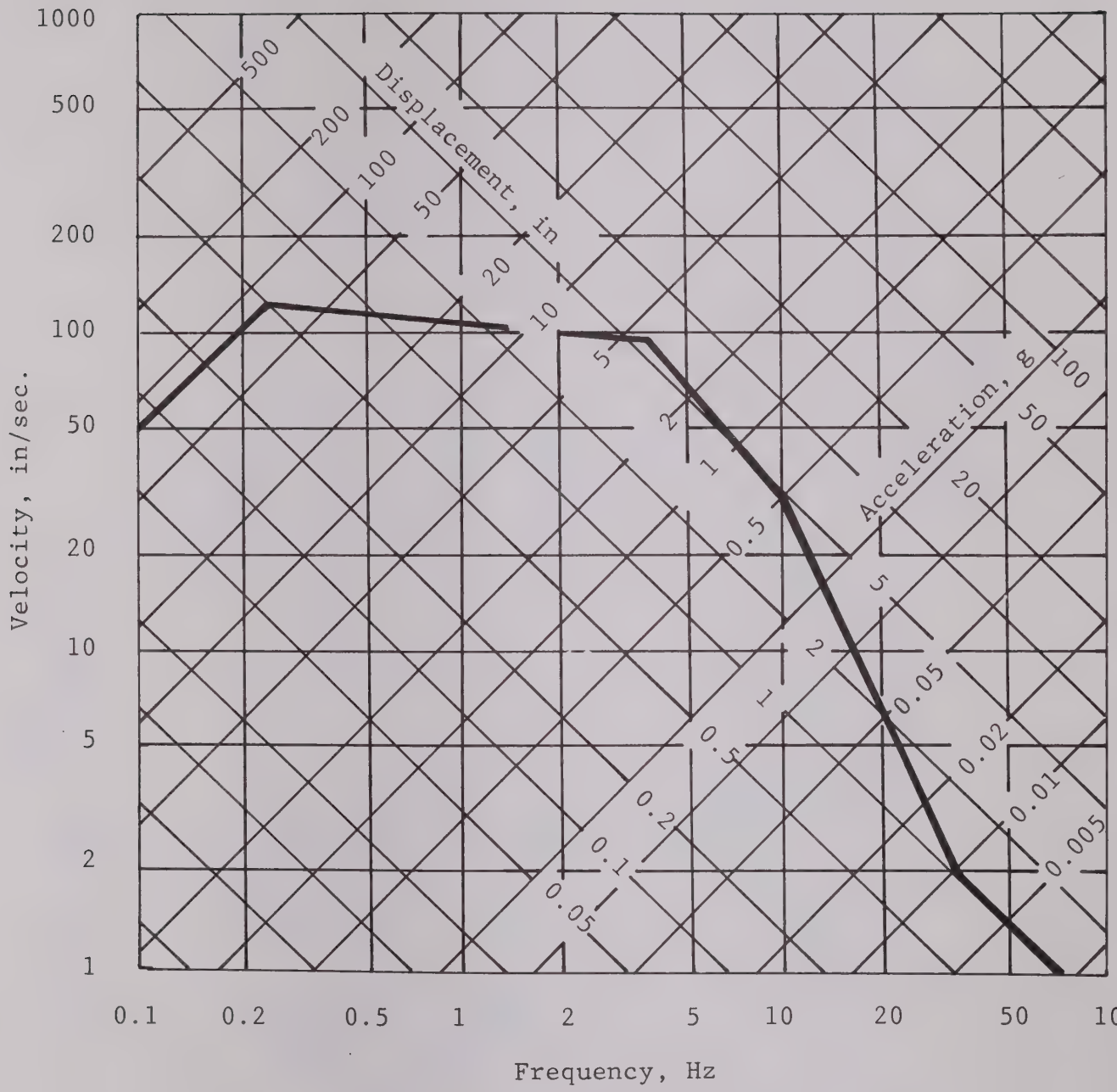



FIGURE E-1. Example Response Spectrum Showing Velocity vs. Frequency

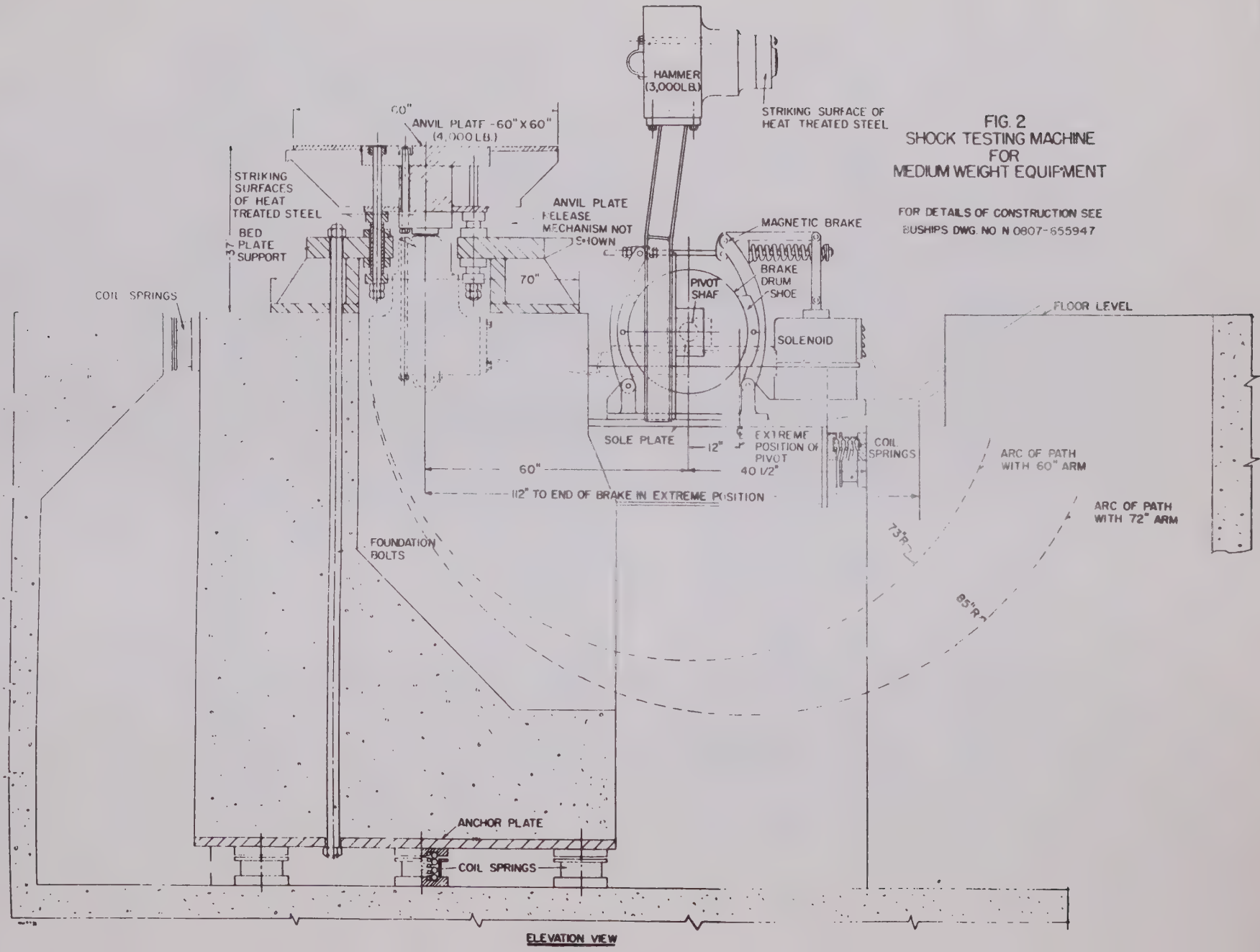
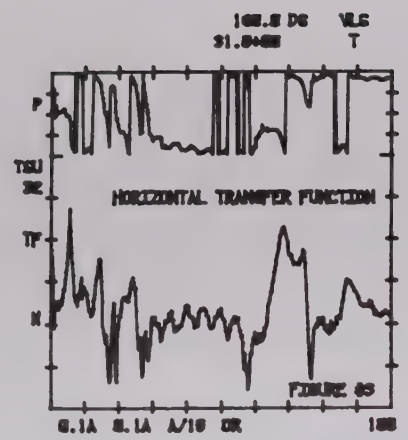


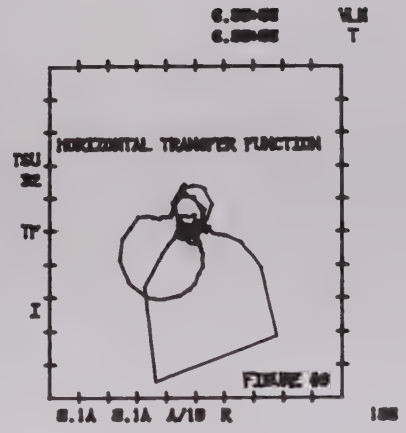

FIG. 2
SHOCK TESTING MACHINE
FOR
MEDIUM WEIGHT EQUIPMENT

FOR DETAILS OF CONSTRUCTION SEE
BUSHIPS DWG. NO N 0807-655947

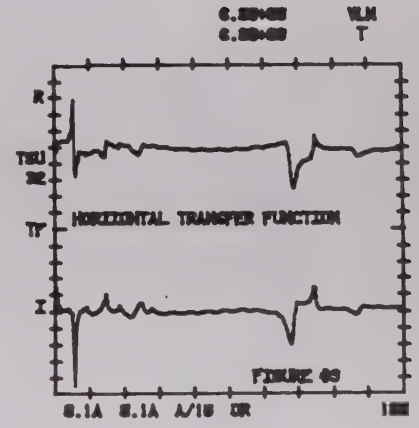
FIGURE E-2




BODE




NYQUIST




REAL AND
IMAGINARY

FIGURE E-3

The transfer functions can be obtained in a manner which is quite harmless to the machinery in question. First the rotating members and then the entire structure must be tested.

1. Rotating Members - Suspend the rotating member on knife edges located at the bearing supports. Mount an accelerometer on each of the tight running clearances of the rotor, such as the wear shrouds. The transfer functions can be obtained by striking the shaft near the bearing locations. Each accelerometer signal should be fed successively into channel B of a two channel Spectrum Analyzer, while channel A receives either the signal from a force gauge mounted on the hammer (for motion/force transfer functions) or the signal from an accelerometer mounted near the bearing locations (for motion/motion tranfer functions). Store these transfer functions in a digital memory. (Refer to Figure E-4.)

1. Entire Structure - With the machine fully assembled, mount it on soft supports. Locate a triaxial accelerometer block on each major mass of the system. Strike the system on one of the mounting feet of the system to obtain transfer functions for each major component in each of the three principal directions. Motion/force or motion/motion transfer functions should be stored depending on whether the non-destructive test input will be specified in terms of motion or a force. (Refer to Figure E-5.)

B. Obtain The Excitation Spectra

The excitation spectra may be well defined by specification as shown for the seismic spectra shown in Figure E-1. If this is not known, it will be necessary to obtain this data by mounting an accelerometer or force transducer on the test rig to be used for the actual tests and to undergo a 'dry run' of the test. Depending on the nature of the test rig, it may be necessary to mount a dummy mass on the rig for this test. Store the excitation spectra.

C. Simulate the Test

It is possible to think of complex multiplication of frequency domain information as the analogous scalar multiplication. Therefore, it can be easily seen that

$$\text{Excitation force} \times \text{(Transfer function)} = \text{Excitation force} \times \frac{\text{(Output motion)}}{\text{(Input force)}} = \text{Excited output motion}$$

and

$$\text{Excitation motion} \times \text{(Transfer function)} = \text{Excitation motion} \times \frac{\text{(Output motion)}}{\text{(Input motion)}} = \text{Excited output motion}$$

This means that the output motion of any component in the system in a given direction will be that component's transfer and proper units.

The total motion of a component can be represented by:

$$\text{Total Motion} = [(\text{Excited Output Motion } x)^2 + (\text{Excited Output Motion } y)^2 + (\text{Excited Output Motion } z)^2]\ 1/2$$

D. Redesigning the Machine

All of the resultant motions obtained from the simulated tests should be used to check two criteria:

1. Force - Any acceleration levels which are high at a particular frequency should be used to calculate the stresses on the given component. Fatigue limits for the material being used must also be considered.

2. Displacement - The displacement vs. frequency curves can be obtained from the acceleration data by doing double integration on the spectrum analyzer. These displacements plus the static and hydronamic deflections of the component must be used on those components with tight running clearances to determine whether a destructive rub will occur during the actual acceptance test.

## E-4. EXAMPLE

In order to verify the technique, a simple machine, which is used normally for the purpose of demonstrating the power of Spectrum Analysis in solving vibration problems, was employed. The machine's response to a typical earthquake spectra was determined. The machine has a slender shaft with a large disk suspended between two bearings. Two proximeters placed at right angles to each other are located on the machine in such a way as to measure the relative motion between the shaft and the machine. (Refer to Figure E-4.)

Step 1:

The vertical transfer function of the machine was determined by attaching the vertcal-reading proximity probe and the output of a hammer instrumented with a force gauge into the two channels of a Nicolet 660B Spectrum Analyzer. The structure of the machine was tapped in the vertical direction at its base and 32 averages of the resulting transfer function were taken. The large number of averages was taken to compensate for the variation in the spectral shape of each hammer blow. Figure E-5 shows this transfer function. Note that there are several resonances in this system between zero and 100 Hz. The coherence was checked and found to be

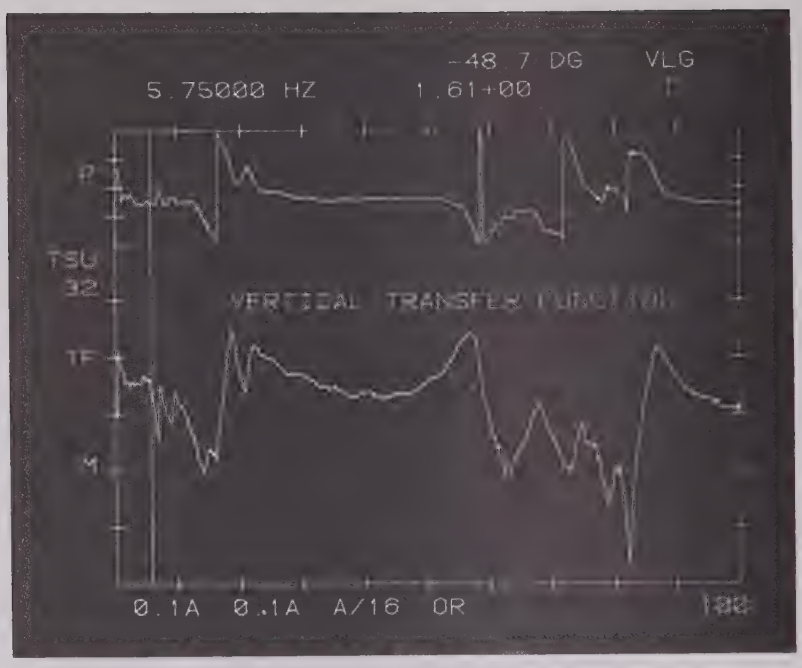



FIGURE E-4

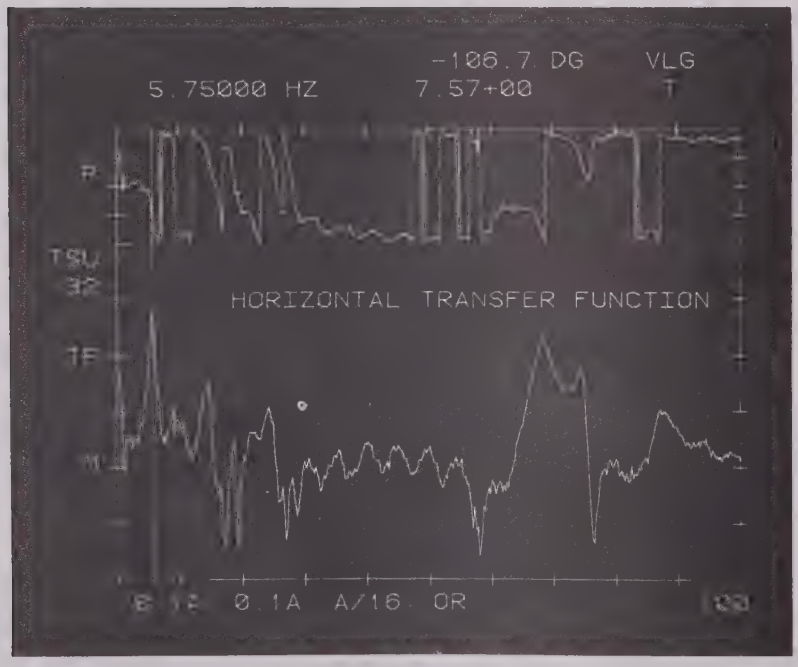



FIGURE E-5

quite good, indicating that a large portion of the response of the shaft was due to the hammer impacts, rather than extraneous sources such as poor signal to noise ratios or other excitations. The transfer function was stored in a 160C floppy disk digital recorder for further use.

Step 2:

The horizontal transfer function of the system was taken by attaching the horizontal-reading proximeter to the 660B and striking the structure at its base and the horizontal direction, gathering 32 averages. This transfer function was also stored in the 160C. (Refer to Figure E-6.)

Step 3:

The earthquake spectra was manually entered into the 660B using the calculation control section of the analyzer. Since the motion readings taken were in terms of displacement in mills, the earthquake spectra was also entered in terms of displacement in mills. (Refer to Figure E-7.)

Step 4:

The response to the transfer function from the earthquake spectral input was calculated using the Complex Math Option of the 660B and can be seen in Figures E-8 and E-9 (the vertical and horizontal responses).

Step 5:

The total motion of a system due to the earthquake was calculated on the 660 using a vector calculation of the vertical and horizontal motion (axial motion was not considered in this example). Note that the maximum excursion is due to static loading (which could easily have been calculated mathematically) plus the dynamic loading measured in this example. The only significant dynamic contribution to motion occurs at 5.75 Hz which is due to the resonance in the horizontal direction. The total motion of the system due to the earthquake is the peak value of the magnitude portion of the total motion from 0-100 Hz and the static, or 0 Hz, component of the motion (not computed by the spectrum analyzer but easily calculated by a simple force balance using the DC component of the earthquake).

## E-5. SUMMARY

This paper has offered a solution to the problem of risking the costly failure of a machine during an environment acceptance test by determining the dynamic characteristics of the machine to be tested using a two-channel Spectrum Analyzer, and mathematically exciting the system's transfer

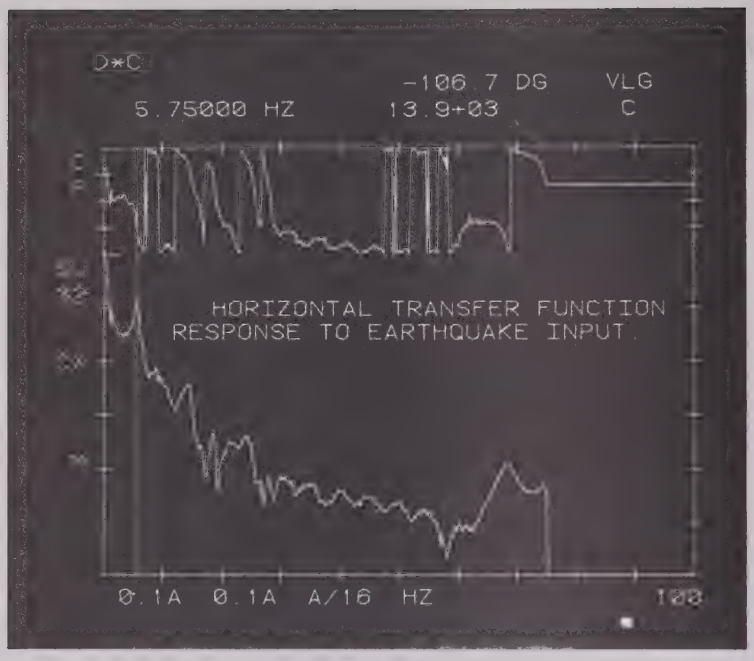



FIGURE E-6

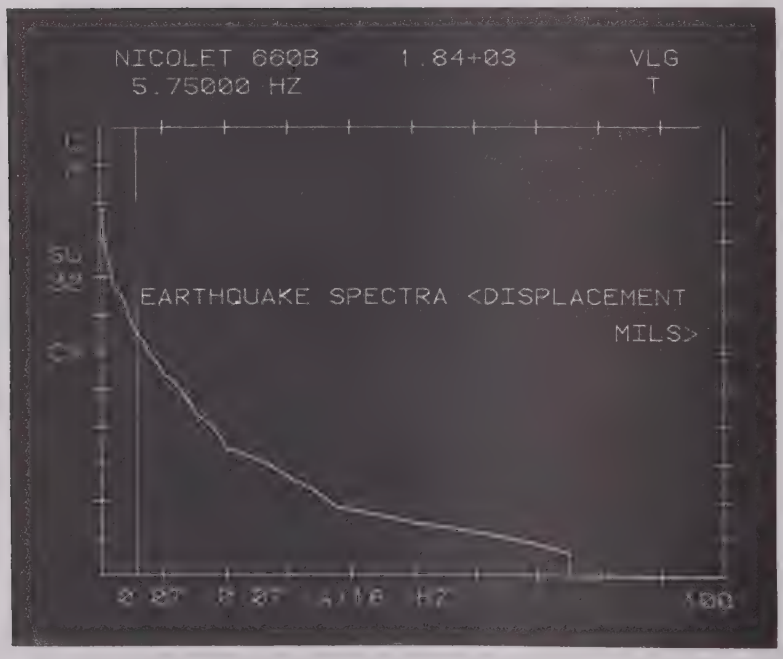



FIGURE E-7

FIGURE E-8

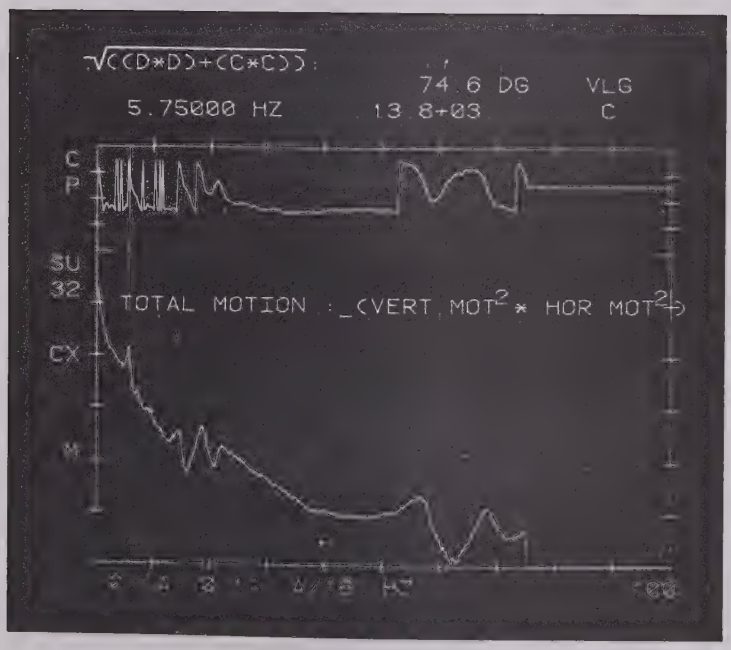



FIGURE E-9

functions with the forcing function the machine will experience during the actual environmental test. A simple example was presented to demonstrate the technique involved.

Note that this same sort of calculation can be used in other areas to answer the question of what will happen to a newly pruchased machine if mounted in an area exhibiting certain ground vibration (such as in the case of mounting a new computer in an office above a large vibration source or a new precision shaft grinding machine in an area which experiences a high level of vibration due to other machine shop and manufacturing functions).

Intentionally blank.

# APPLICATION NOTE G

## MEASUREMENT OF DIRECTIONAL SIGNALS OR NOISE[1]

The determination of the directional characteristics of a sound field can be very useful in identifying interference noise or tracking moving sound sources. The direction of a sound source may be determined through the use of a pair of phase matched cardioid microphones and the 660B Spectrum Calculation Option -8.

Figure G-1 shows the 660B and microphone connections while Figure G-2 describes the physical orientation of the microphones' sensititivity patterns.

The magnitude and angle of sound source C is simply determined through the following relationships:

$$|c| = \sqrt{A^2 + B^2} \qquad (1)$$

$$\phi_c = \tan^{-1} \frac{B}{A} \qquad (2)$$

The following procedure describes how to configure the 660B to compute the quantities of equations 1 and 2.

PROCEDURE:

| | | | |
|---|---|---|---|
| 1. | SYS ReSeT | : | Define initial conditions |
| 2. | Set AVG Type to EXP | : | Exponential averaging |
| 3. | Connect N/S (North/South) Data to Channel A | : | Refer to Figures G-1, G-2 |
| 4. | Connect E/W (East/West) Data to Channel B | : | Refer to Figures G-1, G-2 |
| 5. | Set Attenuator Setting to Same Value[2] | : | |
| 6. | Depress CM | : | Enter Complex Math Mode |
| 7. | Type Equation: "SA:" | : | Complex Math Special |
| 8. | Depress SHIFT 2 VER | : | Verify Equation |
| 9. | Depress View C | : | |

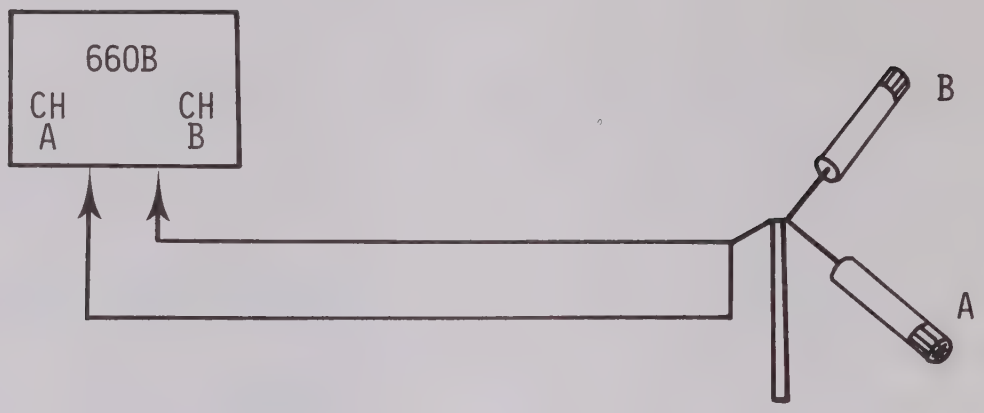



FIGURE G-1.

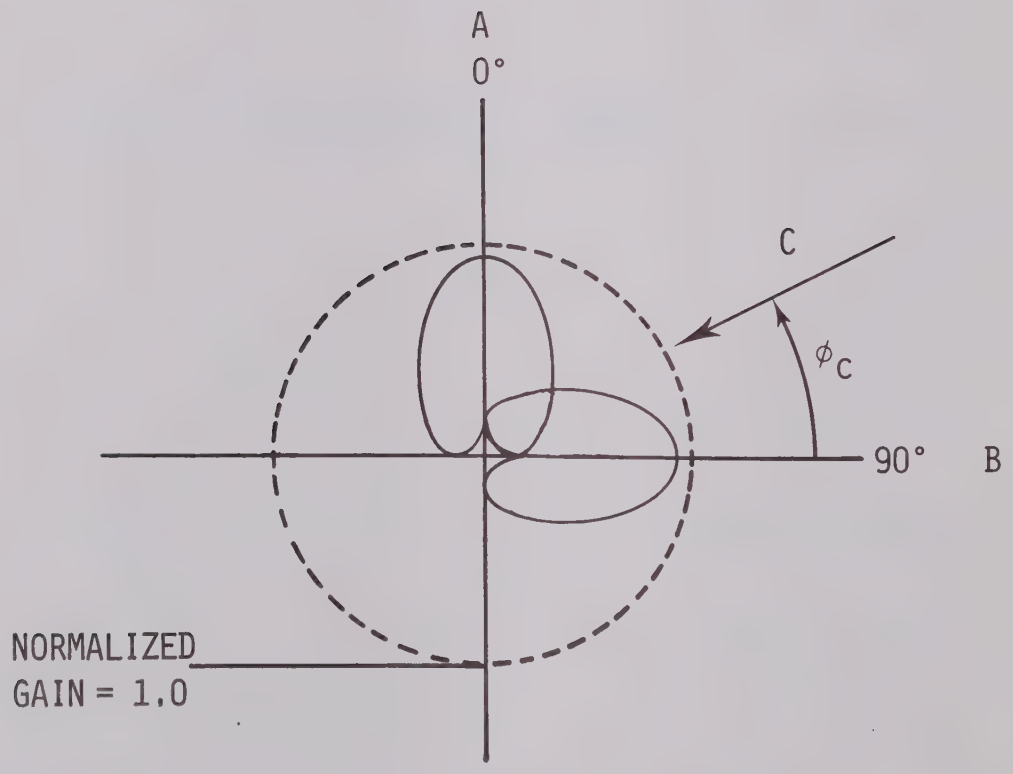



FIGURE G-2.

10. Depress $\phi$/MAG : View Phase, Magnitude Display of Complex Buffer C

11. Start Averager :

The VIEW C, $\phi$/MAG display will now be defined as:

$$\phi = \tan^{-1} \frac{B}{A}$$

$$MAG = \sqrt{A^2 + B^2}$$

where: A = RMS Spectrum of Channel A
B = RMS Spectrum of Channel B

and the direction and magnitude of each frquency component may be directly read with the cursor.

---

[1]Minimum 660B EXEC software is FH.
[2]This step may be eliminated for EXEC software GC and above.

APPLICATION NOTE H

# CALIBRATING THE 660 (or 446) ANALYZER TO READ OUT IN ENGINEERING UNITS

The 660 Analyzer provides three different types of amplitude readouts: (1) amplitude at cursor; (2) overall amplitude; and (3) amplitude between cursors (446 - MARKER and CURSOR). The units may be in volts (V, $V^2$) or engineering reference units (R, $R^2$).

Amplitude at Cursor - the amplitude at cursor is the RMS value of the signal at the present cursor location.

Overall Amplitude - the overall amplitude is the signal's RMS value within the selected frequency range of display.

Amplitude Between Cursors - the amplitude between cursors (446 - MARKER and CURSOR) is the signal's RMS value within the selected frequency range designated by the two cursors.

Step 1 - Determine the Calibration Factor of the Transducer

The three most commonly used transducers are accelerometers, velocity transducers, and displacement transducers. Typical calibration/unit of each type transducer is shown below:

| Transducer Type | Calibration |
|---|---|
| Accelerometer | millivolt/g |
| Velocity | millivolt/inch/sec |
| Displacement | millivolt/mil |

The 660 or 446 Analyzer displays data in engineering units (g, mil, inches/sec, etc.) if it is set to convert from volts (not millivolts) to engineering units desired.

446 - To set the analyzer, place the proper volts/reference (V/R) number in the upper-middle display field of the analyzer. The proper V/R value is simply the calibration factor of the sensor used. For example, if an accelerometer is being used with a 100 mv/g (.100 v/g) sensitivity and $100^{-3}$ V/R is entered in the upper-middle display field, amplitude units of g RMS will be read.

This V/R number is placed in the analyzer memory by holding the CURSOR AMPLITUDE switch in the SET R position and adjusting the GAIN switch until the correct V/R value is displayed in the upper-middle of the display field. After completing this operation, leave the CURSOR AMPLITUDE switch in the R position.

660 - The 660 has two V/EU constants, one for each channel. These constants are set as follows:

1. View the appropriate channel (either A or B, not both and not a cross property).
2. Enter the V/EU conversion factor (using the Calculation Control section).
3. Press SET V/EU.
4. In the amplitude units group, be sure that the LED on the V/EU is OFF and therefore, reading EU; and be sure that the LED on the ABS/REL button is ON.

Step 4 above can be explained as follows: If the V/EU button is in V (LED ON), the V/EU constants are ignored and the 660 reads volts. If the ABS/REL button is in REL (LED OFF), the 660 displays amplitude relative to some pre-set reference. For example, if the highest peak in a display were assigned the relative value 100 by position the cursor on it and pressing: 100 SET LIN , amplitude would read in percent of the peak. Essentially, to use V/EU, the amplitude should be set to read in ABSolute Engineering Units.

The proper V/EU value is simply the calibration factor of the sensor used on that channel. For example, if an accelerometer is being used on channel A, with a 100 mV/g (.100 V/g) sensitivity, then to obtain amplitude readings of g rms instead of V RMS, simply VIEW A and press .1 SET V/EU. If the amplitude units group of buttons is set to read ABSolute EU, amplitude units of g RMS will be read.

Two other factors must be considered in order to to achieve the correct engineering unit calibration. First, since the analyzer must use extremely small and large numbers, scientific notation is used in the display field. Secondly, the analyzer's amplitude readout display is in RMS terms. Therefore, to measure amplitude units in 0-peak or peak to peak units, a simple conversion must be made.*

---

*The remainder of this paper is simply numerical, and is applicable to either the 660 or the 446. V/R is used to mean volts/reference for the 446. Users of 660s should simply read V/EU in place of V/R. This paper applies to each channel of the 660. (NOTE: The 660 requires a two digit exponent so that a V/R of $258-^{6}$ , for example should be entered as 258 EXP -06 SET V/EU.

To read 0-peak amplitude, simply take the RMS value (.707) of the calibration factor and re-enter this new V/R value in the upper-middle display field.

In the previous example, the RMS value of .100 V/g is now .0707 V/g. Changing that value to scientific notation would result in $70.7^{-3}$ being entered in the V/R display field. Amplitude is now being read directly in g 0-peak. If one half of this new (0-pk) V/R value is taken it will be read directly in g (pk-pk). The new V/R value in the example would be $35.4^{-3}$.

Step 2 - Converting Your Calibration Factor to Display Engineering Units as Desired

Proper engineering unit calibration (when integrating or differentiating a signal) requires that the transducer sensitivities be expressed in consistent units of inches/feet or meters. Therefore, for the transducer types listed above, a consistent unit of inches can be established. Velocity sensors are typically calibrated in volts (inch/sec). Displacement sensors typically are calibrated in volts/mil (volts/.001 inches). However, acceleration sensors are not calibrated in easily converted units. Therefore, an alternate expression for acceleration must be utilized. Such an expression is shown below:

1 g = 386.4 inch/sec/sec

If the calibration factor is taken (.100 V/g in the example) and divided by 386.4 inch/sec/sec, a new V/R value will be arrived at that when integrated (x1) by the analyzer will result in velocity (inch/sec) in RMS units.

Example:

$$\frac{.100 \text{ V/g}}{386.4 \text{ inch/sec/sec}} = .000258 \text{ or } 258^{-6}$$

| V/R Setting | | Amplitude Display Readout | |
|---|---|---|---|
| $258^{-6}$ | = | velocity RMS | integrate (x1) |
| $183^{-6}$ | = | velocity 0-peak | integrate (x1) |
| $91.5^{-6}$ | = | velocity pk to pk | integrate (x1) |

If amplitude units of displacement were desired, enter the $258^{-6}$ V/R value in the display field and double integrate through the analyzer. The resulting amplitude readout will be displacement in inch units RMS. To read displacement amplitude directly in mils RMS (.001"), simply divide the V/R value by 1000. The new V/R value in the example would be $258^{-9}$.

Example:

$$\frac{.100 \text{ V/g}}{386.4 \text{ inch/sec/sec}} = .000258 \text{ or } 258^{-6}$$

$$\frac{.000258}{1000} = .000000258 \text{ or } 258^{-9}$$

| V/R Setting | | Amplitude Display Readout |
|---|---|---|
| $258^{-6}$ | = | displacement (inches) RMS integrate (x2) |
| $258^{-9}$ | = | displacement (mils) RMS integrate (x2) |
| $183^{-9}$ | = | displacement (mils) 0-pk integrate (x2) |
| 91.2 | = | displacement (mils) pk-pk integrate (x2) |

The following three tables show how to convert to several commonly used engineering units. Be sure to utilize the proper table for the proper transducer type.

TABLE H-1

Initial Calibration Sensitivity of Volts/g Accelerometers

| VOLTS/REFERENCE (V/R) VALUES | DESIRED ENGINEERING UNIT MEASUREMENT | | |
|---|---|---|---|
| | Acceleration - | Velocity integrate x1 | Displacement integrate x2 |
| Transducer Sensitivity volt/g | g (RMS) | -- | -- |
| Volts/g x .707 | g (0-pk) | -- | -- |
| $\frac{\text{Volts/g x .707}}{2}$ | g (pk-pk)* | -- | -- |
| Volts/g x $2.6 \times 10^{-3}$ | -- | inches/sec (RMS) | inches (RMS) |
| Volts/g x $2.6 \times 10^{-3}$ x .707 | -- | inches/sec* (0-pk) | inches (0-pk) |
| $\frac{\text{Volts/g x } 2.6 \times 10^{-3} \text{ x .707}}{2}$ | -- | inches/sec (pk-pk) | inches (pk-pk) |
| Volts/g x $2.6 \times 10^{-6}$ | -- | mils/sec (RMS) | mils(RMS) |
| Volts/g x $2.6 \times 10^{-6}$ x .707 | -- | mils/sec (0-pk) | mils(0-pk) |
| $\frac{\text{Volts/g x } 2.6 \times 10^{-6} \text{ x .707}}{2}$ | -- | mils/sec (pk-pk) | mils(pk-pk)* |

*Designates most commonly used engineering units.

TABLE H-2

Initial Calibration Sensitivity of Volts/Inch/Sec

Velocity Transducer

| VOLTS/REFERENCE (V/R) VALUES | DESIRED ENGINEERING UNIT MEASUREMENT | | |
|---|---|---|---|
| | Acceleration differentiation x1 | Velocity - | Displacement integrate x1 |
| Transducer Sensitivity Volts (inch/sec) | -- | inches/sec (RMS) | inches (RMS) |
| Volts (inch/sec) x .707 | -- | inches/sec* (0-pk) | inches (0-pk) |
| $\frac{\text{Volts/(inch/sec) x .707}}{2}$ | -- | inches/sec (pk-pk) | inches (pk-pk) |
| Volts/(inch/sec) x $10^{-3}$ | -- | mils/sec (RMS) | mils (RMS) |
| Volts/(in/sec) x $10^{-3}$ x .707 | -- | mils/sec (0-pk) | mils (0-pk) |
| $\frac{\text{Volts/(in/sec) x } 10^{-3} \text{ x .707}}{2}$ | -- | mils/sec (pk-pk) | mils* (pk-pk) |
| Volts/(in/sec) x (3.9 x $10^2$) | g (RMS) | -- | -- |
| Volts/(in/sec) x (3.9 x $10^2$) x .707 | g (0-pk)* | -- | -- |
| $\frac{\text{Volts/(in/sec) x(3.9 x } 10^2) \text{ x .707}}{2}$ | g (pk-pk) | -- | -- |

*Designates most commonly used engineering units.

TABLE H-3

Initial Calibration Sensitivity of Volts/Mil

Displacement Transducer

| VOLTS/REFERENCE (V/R) VALUES | DESIRED ENGINEERING UNIT MEASUREMENT | | |
|---|---|---|---|
| | Acceleration differentiation x2 | Velocity differentiation x 1 | Displacement - |
| Transducer Sensitivity Volts/mil | -- | -- | mils (RMS) |
| Volts/mil x .707 | -- | -- | mils (0-pk) |
| $\frac{\text{Volts/mil x .707}}{2}$ | -- | -- | mils (pk-pk)* |
| Volts/mil x $(10)^3$ | | inches/sec (RMS) | inches (RMS) |
| Volts/mil x $(10)^3$ x .707 | | inches/sec* (0-pk) | inches (0-pk) |
| $\frac{\text{Volts/mil x } (10)^3 \text{ x .707}}{2}$ | | inches/sec (pk-pk) | inches (pk-pk) |
| Volts/mil x $(3.9 \times 10^5)$ | g (RMS) | -- | -- |
| Volts/mil x $(3.9 \times 10^5)$ x .707 | g (0-pk)* | -- | -- |
| $\frac{\text{Volts/mil x } (3.9 \times 10^5) \text{ x .707}}{2}$ | g (pk-pk) | -- | -- |

*Designates most commonly used engineering units.

# APPENDIX C

## APPLICATION NOTES

Application notes may follow which may be useful to the 660 user.

ADDITIONAL REMOTE CONTROL OPERATIONS

DISPLAY SECTION

| | |
|---|---|
| SET Recall | |
| SET Compare | |
| SET Equalize | |
| CLEAR Recall, Compare, and Equalize | |
| SET View C | |
| RESET View C | |

CURSOR READS SECTION (AMPLITUDE UNITS)

| | |
|---|---|
| SET dB/LIN to dB | |
| SET V/EU to V | |
| SET ABS/REL to ABS | |
| SET PER Hz to ON | |
| RESET dB/LIN to LIN | U8 |
| RESET V/EU to EU | U9 |
| RESET ABS/REL to REL | UA |
| RESET PER Hz to OFF | UP |

SCALES SECTION

| | |
|---|---|
| SET AMPL LOG/LIN to LOG | G2 |
| SET FREQ LOG/LIN to LOG | G3 |
| RESET AMPL LOG/LIN to LIN | G4 |
| RESET FREQ LOG/LIN to LIN | G5 |

CAPTURE CONTROL SECTION

| | |
|---|---|
| Force input buffer to hold | S |
| Release input buffer | " |

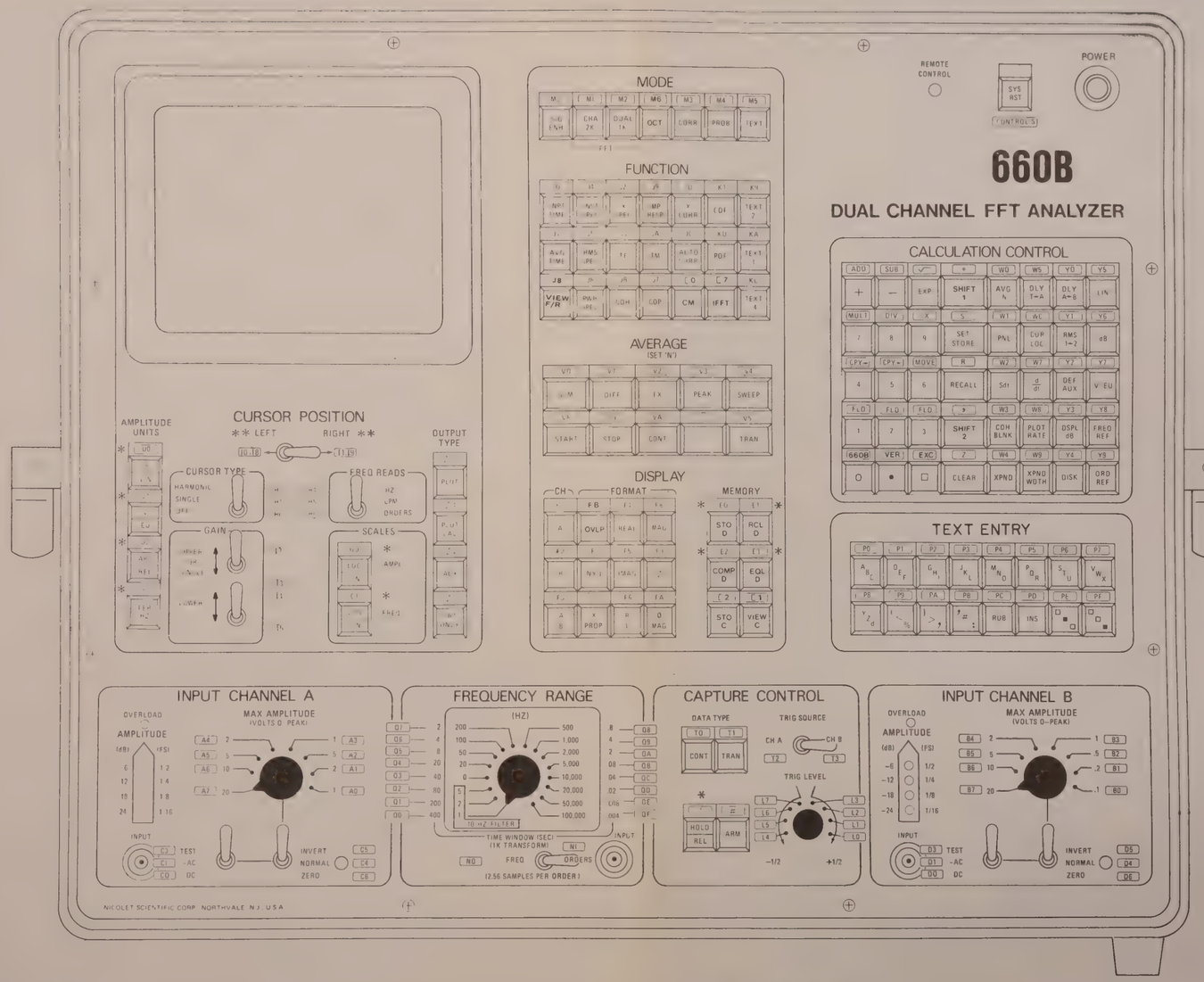
ADDITIONAL COMMANDS

| | |
|---|---|
| SET Complex Math Mode | |
| RESET Complex Math Mode | |
| SET IFFT on View C | |
| RESET IFFT (Do FFT) on View C | |
| Toggle Complex Math Mode | |
| Toggle IFFT (View C TIME/FREQ) | |
| External I/O Blocksize Control | WA |
| External I/O Initiate Commands | |
| Input buffer n* from RS232-C interface | >n |
| Output from n over RS232-C interface | =n |
| Input to n from IEEE-488 interface | @n |
| Output from n over IEEE-488 interface | ?n |

*n is a hexidecimal digit ranging from zero through F.

| | |
|---|---|
| Lock-out Front Panel Operation | 'DC1' : (CNTRL/Q) |
| Enable Front Panel Operation | 'DC4' : (CNTRL/T) |
| Enter Entry Field ALPHA Mode | 'RS' : (CNTRL/^) |
| Exit Entry Field ALPHA Mode | 'FS' : (CNTRL/ ) |
| Invert Characters in Entry Field | 'BEL' : (CNTRL/G) |
| Output Status Byte Over IEEE-488 Interface | 'BS' : (CNTRL/H) |
| Output Status Byte Over RS232-C Interface | 'HT' : (CNTRL/I) |
| Used Internally | CNTRL/A through CNTRL/F) |
| | CARRIAGE RETURN |
| | LINE FEED |

The codes between quotes are the mnemonics for single ASCII characters generated by the keystrokes between the parentheses. 'CNTRL/' means to hold the CNTRL key while depressing the character following the slash, e.g. CNTRL/S means depress CNTRL while pressing S.




NOTE:

* = THESE COMMANDS COMPLEMENT THE CURRENT STATE OF THE ASSOCIATED PUSHBUTTON. COMMANDS ALSO EXIST TO SELECT A DESIRED STATE. (SEE THE LIST OF ADDITIONAL REMOTE CONTROL OPERATIONS.)

** = I0 and I1 MOVE THE CURSOR A SMALL STEP IN THE APPROPRIATE DIRECTION. I8 and I9 USE A LARGE STEP.

Ø = THE SYMBOL FOR THE LETTER O.

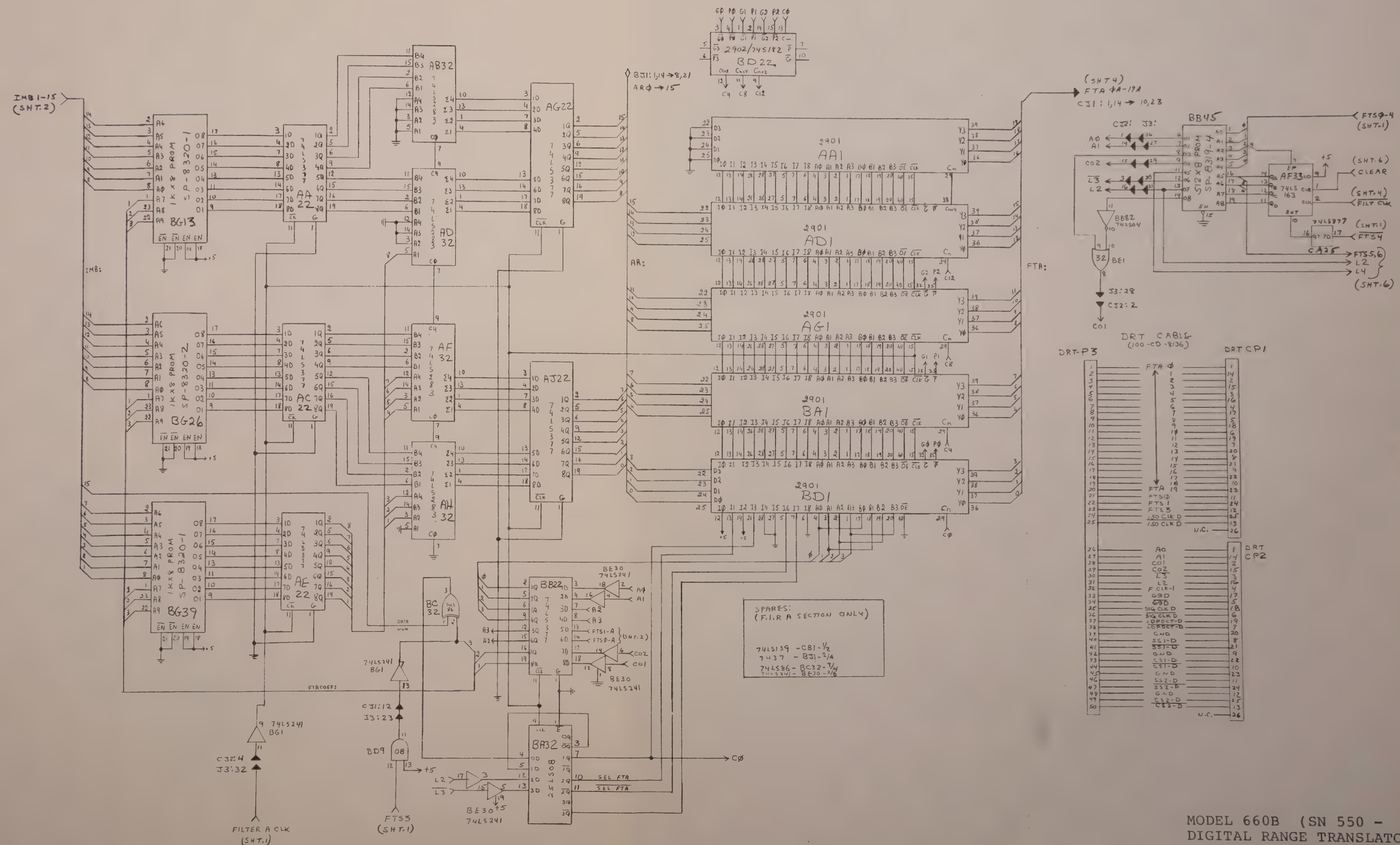
0 = THE SYMBOL FOR THE DIGIT 0.

SEE DIAGRAM FOR CALCULATION CONTROL COMMAND CODE.

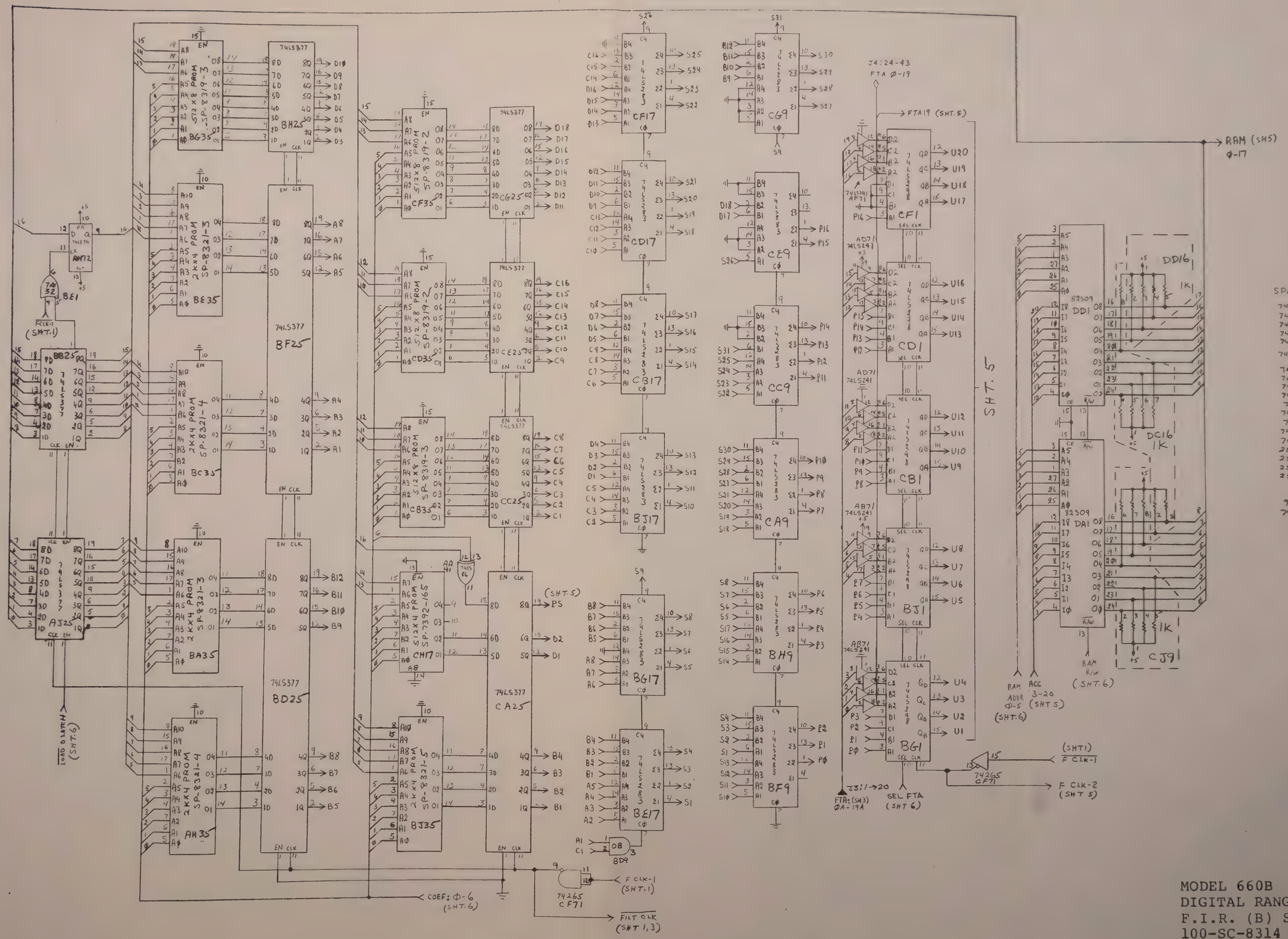
REMOTE CONTROL COMMAND FOR 660B
FIGURE 19-5

MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
COMPLEX SYNTHESIZER
100-SC-8314
SHEET 1 of 6 REV B
4-82

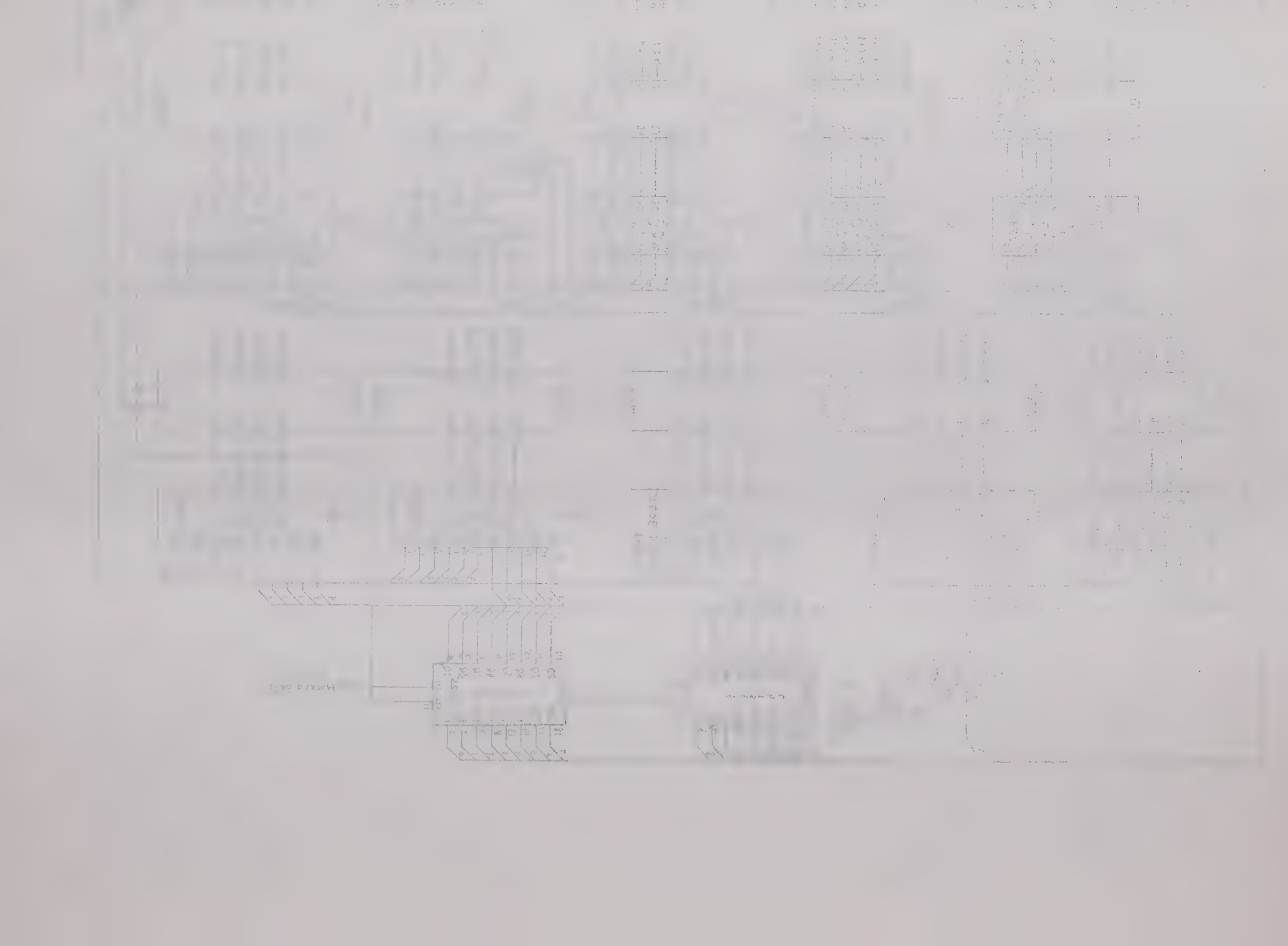
MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
INPUT MULTIPLIER
100-SC-8314
SHEET 2 of 6 REV B
4-82




MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
F.I.R. (A) SECTION
100-SC-8314
SHEET 3 of 6 REV B
4-82

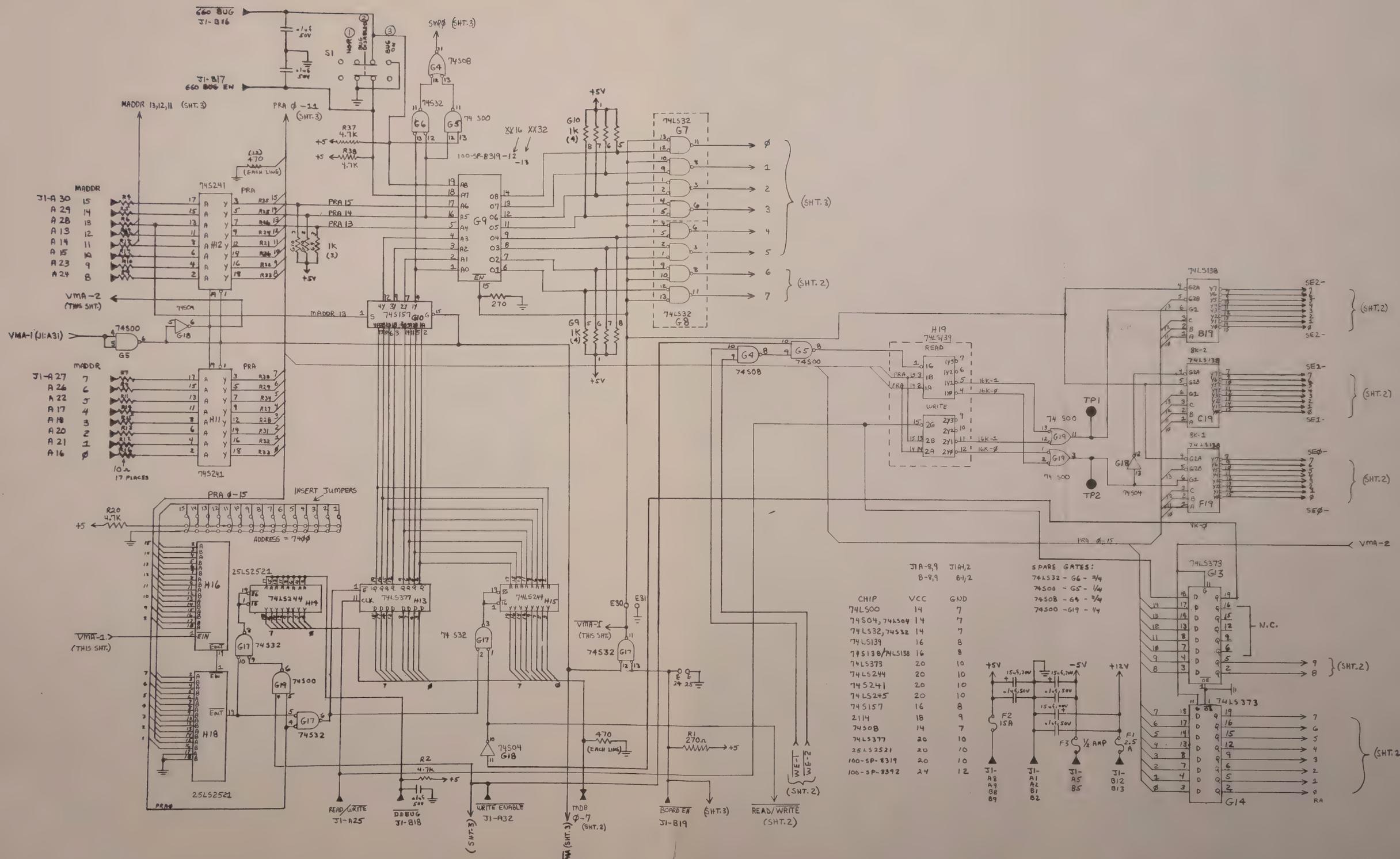



MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
F.I.R. (B) SECTION, PG.1
100-SC-8314
SHEET 4 of 6 REV B
4-82



MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
F.I.R. (B) SECTION, PG. 2
100-SC-8314
SHEET 5 of 6 REV B
4-82

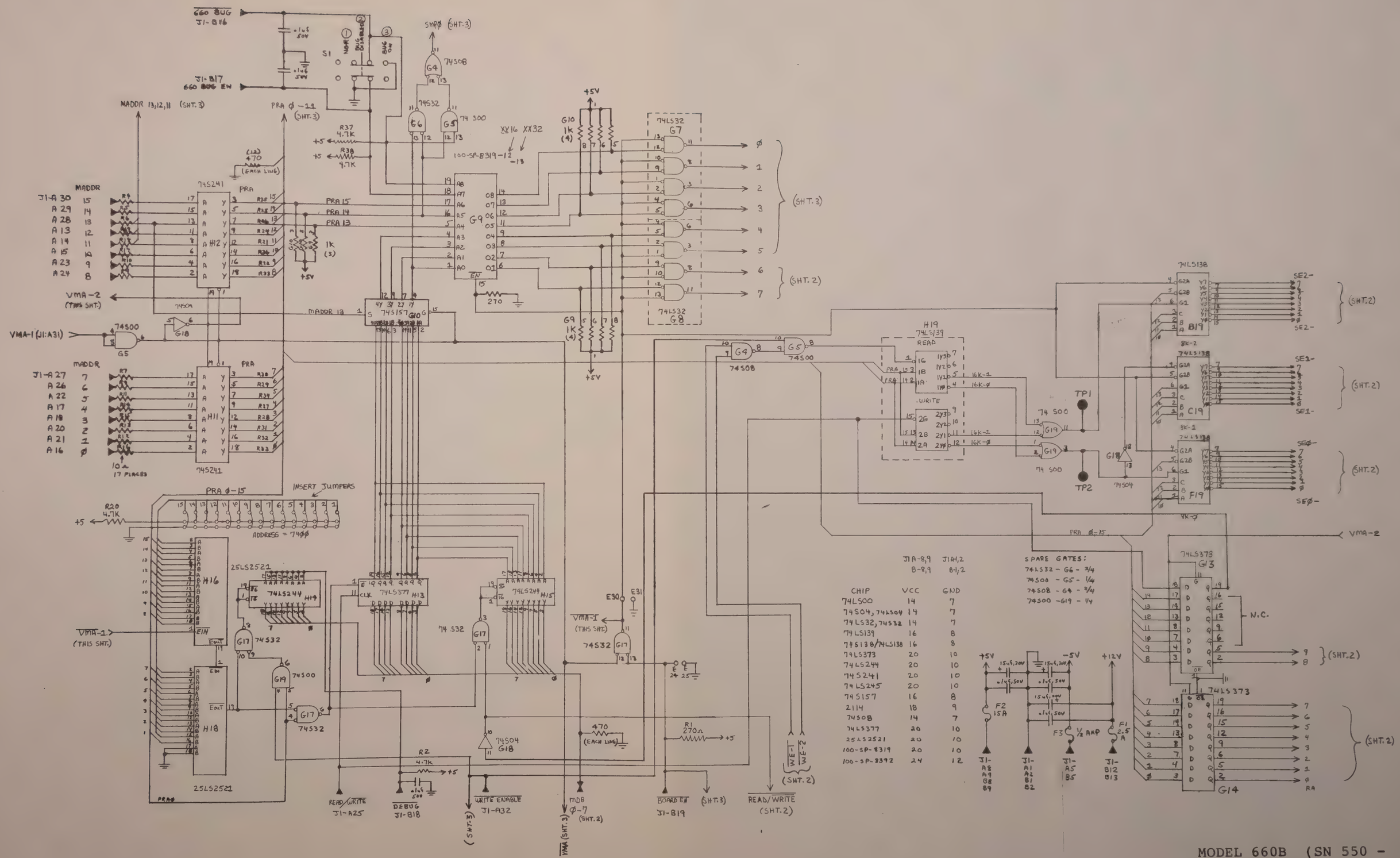
MODEL 660B (SN 550 - )
DIGITAL RANGE TRANSLATOR
FILTER (A & B) TIMING
100-SC-8314
SHEET 6 of 6 REV B
4-82




| CHIP | VCC | GND |
|---|---|---|
| 74LS00 | 14 | 7 |
| 74S04, 74LS04 | 14 | 7 |
| 74LS32, 74S32 | 14 | 7 |
| 74LS139 | 16 | 8 |
| 74S138/74LS138 | 16 | 8 |
| 74LS373 | 20 | 10 |
| 74LS244 | 20 | 10 |
| 74S241 | 20 | 10 |
| 74LS245 | 20 | 10 |
| 74S157 | 16 | 8 |
| 2114 | 18 | 9 |
| 74S08 | 14 | 7 |
| 74LS377 | 20 | 10 |
| 25LS2521 | 20 | 10 |
| 100-SP-8319 | 20 | 10 |
| 100-SP-8392 | 24 | 12 |

J1A-8,9 B-8,9 J1A-1,2 B-1,2

MODEL 660B (SN 550 - )
MAIN MEMORY
100-SC-8594
SHEET 1 of 3 REV B
4-82

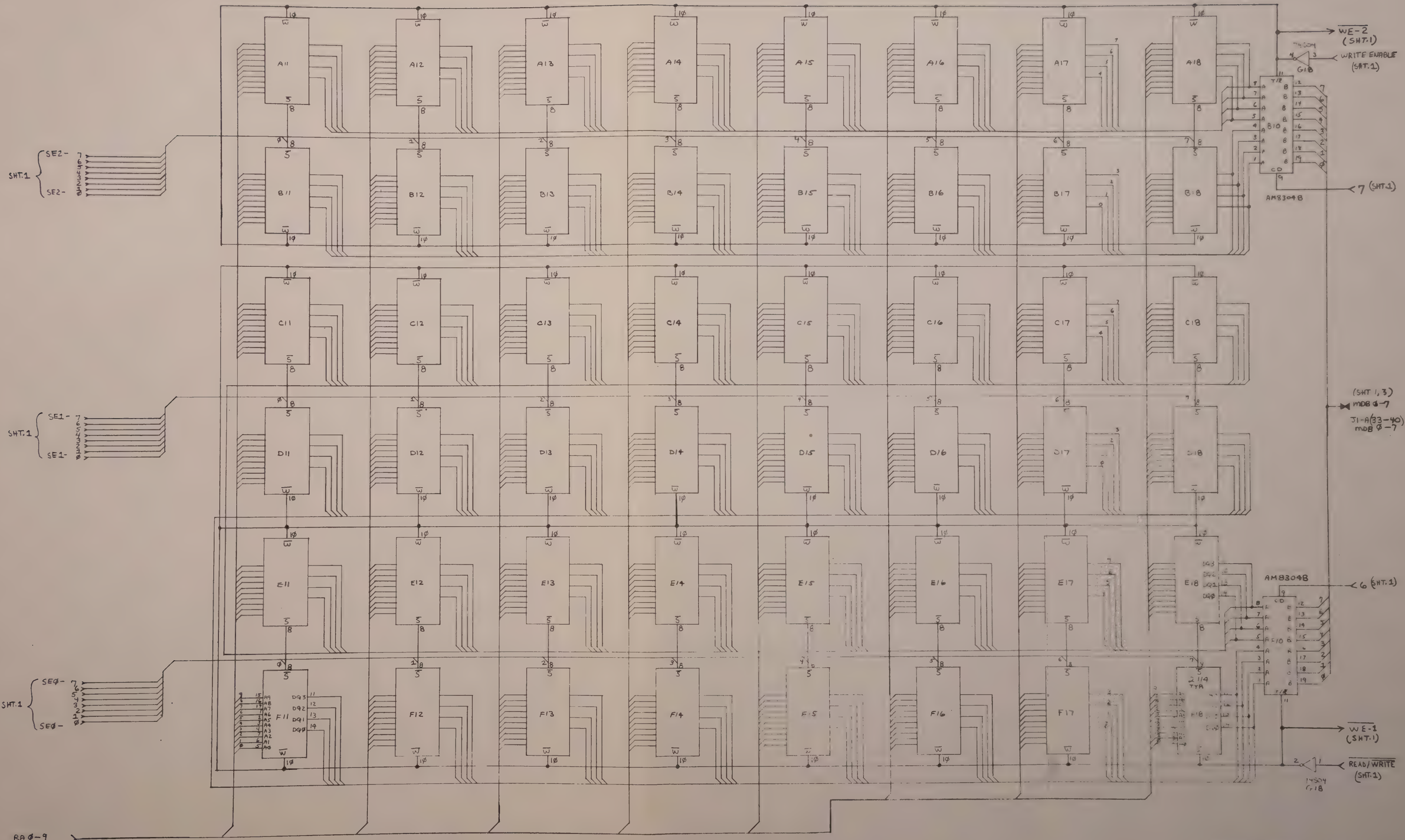



| CHIP | VCC | GND |
|---|---|---|
| 74LS00 | 14 | 7 |
| 74S04, 74LS04 | 14 | 7 |
| 74LS32, 74S32 | 14 | 7 |
| 74LS139 | 16 | 8 |
| 74S138/74LS138 | 16 | 8 |
| 74LS373 | 20 | 10 |
| 74LS244 | 20 | 10 |
| 74S241 | 20 | 10 |
| 74LS245 | 20 | 10 |
| 74S157 | 16 | 8 |
| 2114 | 18 | 9 |
| 74S08 | 14 | 7 |
| 74LS377 | 20 | 10 |
| 25LS2521 | 20 | 10 |
| 100-SP-8319 | 20 | 10 |
| 100-SP-8392 | 24 | 12 |

J1A-8,9 J1A1,2
B-8,9 B-1,2

SPARE GATES:
74LS32 - G6 - 3/4
74S00 - G5 - 1/4
74S08 - G4 - 3/4
74S00 - G19 - 1/4

MODEL 660B (SN 550 - )
MAIN MEMORY
100-SC-8594
SHEET 1 of 3 REV B
4-82




MODEL 660B (SN 550 - )
MAIN MEMORY
100-SC-8594
SHEET 2 of 3 REV B
4-82

-5 INSERT FOR TMS2716 BUSS BAR NORMAL C
+5 E31 E32
PRA 11 (SHT.1) INSERT FOR INTEL 2732
+12V INSERT FOR TMS2716 BUSS BAR
PRA 10 (SHT.1) E19 E20 D REMOVE FOR TMS2716
(SHT.1) PRA 9 8 7 6 5 4 3 2 1 PRA Ø

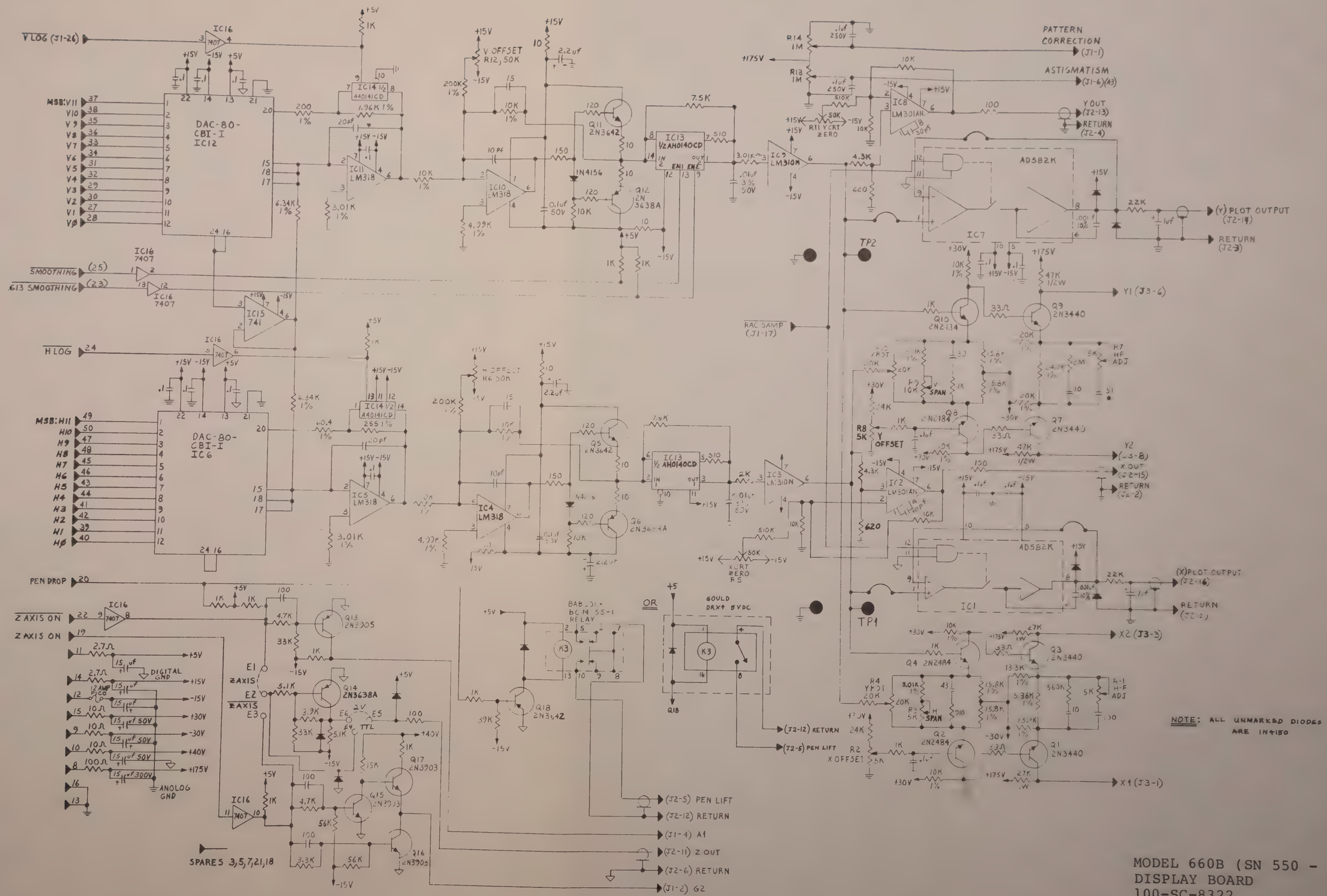
G18 74S04
PRA15 (SHT.1)
PRA1Ø
ADD JUMPERS Ø REMOVE CHIP FOR TMS2716
WRITE ENABLE (SHT.1)
INSERT DOTTED JUMPERS FOR 2732 OR TMS2532
SMPØ (SHT.1)
MADDR 13 MADDR 12 MADDR 11
INSERT JUMPERS FOR INTEL 2716 OR TMS 2516
G3 74S138
VMA (SHT.1)
SPARE PROMS
INSERT FOR OPT 03 08 38 PROMS

-59 A2 -60 A3 -61 A4 -62 A5 -63 A6 -64 A7 -65 A8 -66 A9
-51 B2 -52 B3 -53 B4 -54 B5 -55 B6 -56 B7 -57 B8 -58 B9
-43 C2 -44 C3 -45 C4 -46 C5 -47 C6 -48 C7 -49 C8 -50 C9
-35 D2 -36 D3 -37 D4 -38 D5 -39 D6 -40 D7 -41 D8 -42 D9
-27 E2 -28 E3 -29 E4 -30 E5 -31 E6 -32 E7 -33 E8 -34 E9
-20 F3 -21 F4 -22 F5 -23 F6 -24 F7 -25 F8 -26 F9
470 470(8)
A1 B1 C1 D1 E1 F1 74S241
74S04 G1
<5 (SHT.1) <4 (SHT.1) <3 (SHT.1) <2 (SHT.1) <1 (SHT.1) <Ø (SHT.1)
MDB Ø-7 (SHT.2)

PRA G 21 D 19 A9 23 A8 22 A7 1 A6 2 A5 3 A4 4 A3 5 A2 6 A1 7 A Ø 8
100-SC-8392-19 F2 TYP.
07 06 05 04 03 02 01 00 17 16 15 14 13 11 10 9 18 20

PRA11 (SHT.1)
G2 74S138
INSERT JUMPERS + REMOVE CHIP FOR TMS2532
MADDR 11 12 13 (SHT.1)
(SHT.1) ASYNC ENABLE

MODEL 660B (SN 550 - )
MAIN MEMORY
100-SC-8594
SHEET 3 of 3 REV B
4-82




NOTE: ALL UNMARKED DIODES ARE 1N4150

MODEL 660B (SN 550 - )
DISPLAY BOARD
100-SC-8322
SHEET 1 of 1

REV B
4-82

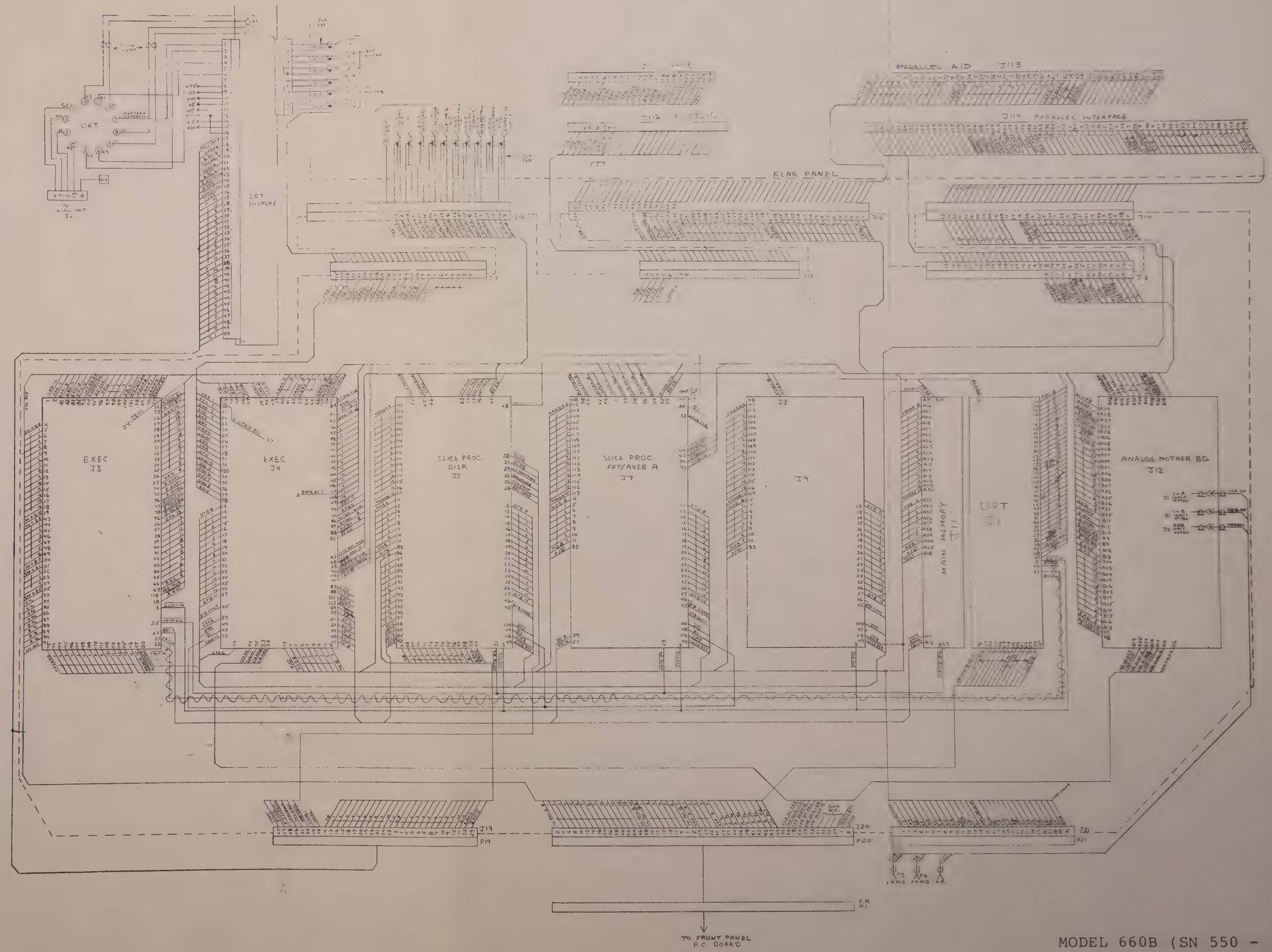
REG. BD.

REG. BD.

RECT. BD.

* = HEAT SINK

MODEL 660B (SN 550 - )
LINEAR SUPPLY
100-SC-8236
SHEET 1 of 1 REV B
4-82




MODEL 660B (SN 550 - )
INTERCONNECTION DIAGRAM
100-SC-8703
SHEET 1 of 2 REV B
4-82

FRONT PANEL
E60
E61
POWER
REAR PANEL FANS
UPPER
LOWER
REAR PANEL TEST POINTS
GND
+5VD
100 Y4 W
16 GA BLK
16 GA WHT
RED
BLK
WHT
GRN
20 GA
20 GA
20 GA
20 GA
22 GA BLU
22 GA BLK
22 GA RED
22 GA BLK
GRN
CRT ANODE
22 GA
CRT SOCKET
A4
G1
HK
H
A2
4 W WIRE
HV
P3
J3
LINEAR SUPPLY
AC
J4
P4
TB1
AC
ACC
16 GA BLK
16 GA WHT
BRAID
AC
ACC
AC GND
SENSE +
SENSE -
H.P. SUPPLY
+5V 100A
+
-
FILTER A BD.
16 GA. WHT
+5
VCC
16 GA. BLK
J1
+5
BUSS
J1
BUSS
DIGITAL MOTHER BD.
DC
J2
P2
RIBBON
AGND BLU
AGND ORG
+5VA BRN
+15V YEL
-15V RED
+30V GRN
-30V WHT
+5V BLK
+175V GRY
N.C.
+5VA
AGND BLK
+5VA WHT
+15V BRN
-15V RED
N.C.
-15V
AGND BLU
+5VA GRY
+15V PUR
-15V ORG
+5VD
DGND
16 GA
GRN 16 GA BRAID
REAR PANEL BRAID
BRAID
FRONT PANEL
MAIN FRAME
16 GA WHT
16 GA BLK
12GA WHT
+5VD
DGND
12GA BLK
BRAID
BUSS 1/4" BRAID
BUSS 1/4 BRAID
J1 - A6,A9,B8,B9
J3 - 39,40,79,80,119,120
J5 - 39,40,79,80,119,120
J7 - 39,40,79,80,119,120
J9 - 39,40,79,80,119,120
J1 - A1,A2,B1,B2
J3 - 1,2,41,42,81,82
J5 - 1,2,41,42,81,82
J7 - 1,2,41,42,81,82
J9 - 1,2,41,42,81,82
DITIGAL MOTHER BD.
20G +5V
IN914
IN914
IN914
20 GA
2V
2V
GRY
INSULATED STANDOFFS
510Ω
1/4W 5%
IN750A
(J4-111) CMOS +V
(J4-112) D GND
(J12-A5, B5) +15V
(J12-A3, B3) AGND
CRT DISP. BD. J1
A3,B3
A1,B1
A5,B5
A4,B4
J12
DIGITAL MOTHER BD.
FRONT PANEL

MODEL 660B (SN 550 - )
INTERCONNECTION DIAGRAM
100-SC-8703
SHEET 2 of 2
REV B
4-82

SAME AS B CKT

A FP BNC

B FP BNC

SYNTHESIZER (OPTIONAL)

XPND ORIGIN IN J109 (R PNL)

DIGITAL MOTHER BD. J21

BANDPASS FILTER (OPTIONAL)

TRANS ORIGIN

EXT SAMP.

(FRONT PNL)

J1 A-INPUT ATTEN.

J5 A-FILTER#4 (1,2,5,HZ) OR A-TRANSLATOR (OPTIONAL)

J9 B-FILTER#4 (1,2,5,HZ) OR B-TRANSLATOR (OPTIONAL)

J13 B-INPUT ATTEN

J4 A-FILTER#3 (100K HZ)

J6 A-A/D CONV.

J8 B-A/D CONV.

J10 B-FILTER#3 (100K HZ)

J2 A-FILTER#1

J3 A-FILTER#2

J11 B FILTER#2

J12 B FILTER#1

J7 SAMP. CONT.

TO EXEC

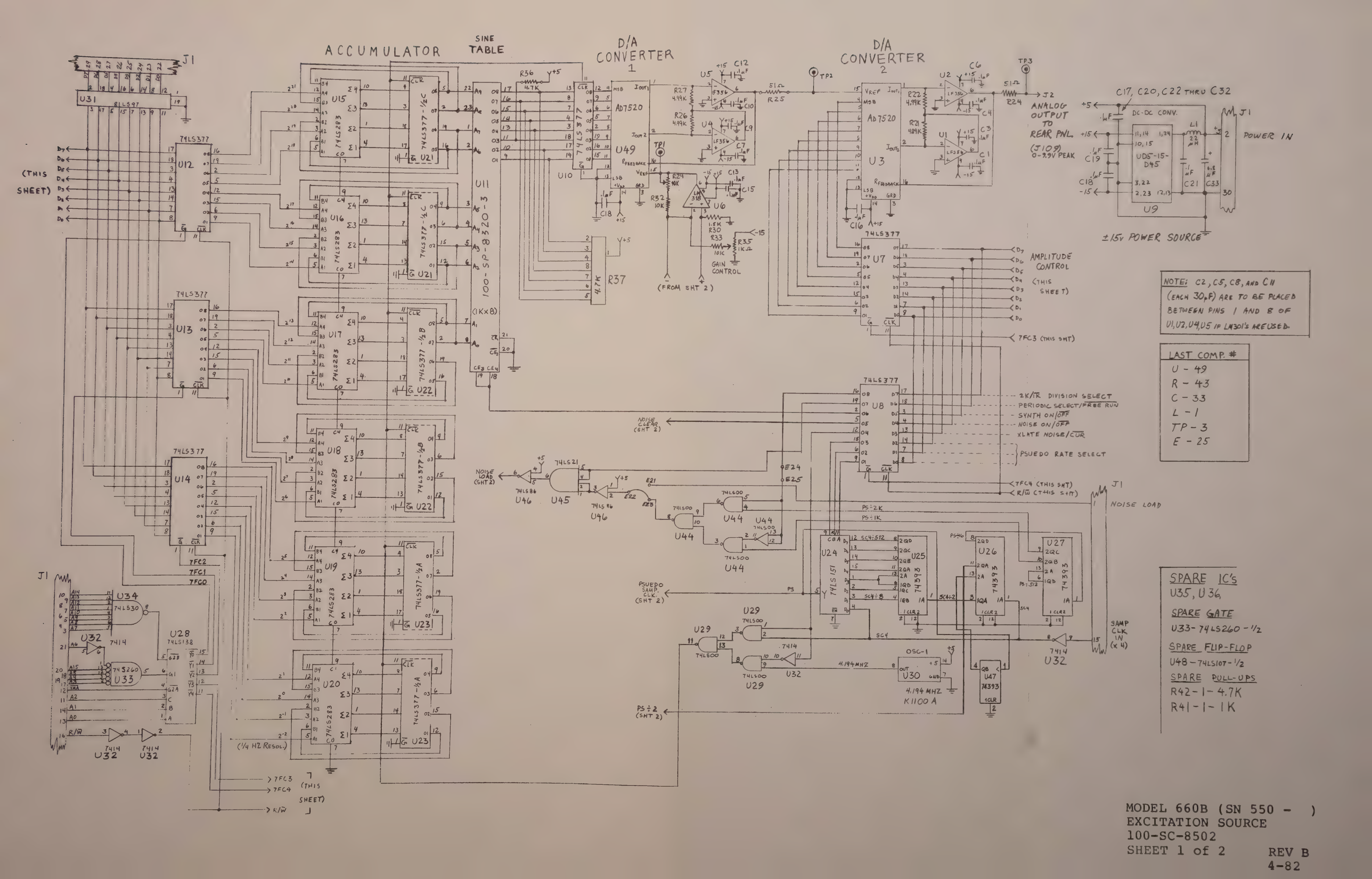
NOTE:

* = REMOVE FOR 1,2,5,HZ

** = REMOVE FOR 1,2,5,HZ OR RANGE TRANSLATION

*** = ELIMINATES FILTER #3

MODEL 660B (SN 550 - )
FRONT END INTERCONNECT
100-SC-8024
SHEET 1 of 1 REV B
4-82




NOTE: C2, C5, C8, AND C11 (EACH 30pF) ARE TO BE PLACED BETWEEN PINS 1 AND 8 OF U1, U2, U4, U5 IF LM301's ARE USED.

| LAST COMP. # |
|---|
| U - 49 |
| R - 43 |
| C - 33 |
| L - 1 |
| TP - 3 |
| E - 25 |

SPARE IC's
U35, U36

SPARE GATE
U33 - 74LS260 - 1/2

SPARE FLIP-FLOP
U48 - 74LS107 - 1/2

SPARE PULL-UPS
R42 - 1 - 4.7K
R41 - 1 - 1K

MODEL 660B (SN 550 - )
EXCITATION SOURCE
100-SC-8502
SHEET 1 of 2

REV B
4-82

R38 4.7K
R40 4.7K
R42 4.7K
R39 1K
R41 1K
R43 1K
+5
SPARES
R20
R19
R18
R16
R15
R14
R13
R17
R12
R11
R8
R7
R6
R4
R3
R2
R1
→ SHT1 (- INPUT TO SUMMING AMP)
→ SHT1 (+ INPUT TO SUMMING AMP)
74LS194 (TYP.)
U37
U38
U40
U41
U42
E20
E19
E18
E17
E16
E15
E14
E13
E12
E11
E10
E9
E8
E7
E6
E5
E4
E3
E2
E1
74LS86
U46
74LS21
U45
74LS00
U29
74LS107
U48
U32
7414
NOISE CLEAR
PSEUDO SAMP. CLK
÷ 2
NOISE LOAD
SHT 1
ZERO DETECT

R1, R11 = 392 K
R3, R9 = 40.2K
R4, R8 = 15.8K
R5, R7 = 9.76K
R6 = 8.66K
R2, R10, R12-R20 ARE SPARES

...GL 660B (SN 550 ...
...ITATION SOURCE
100-56-8502
SHEET 2 of 2 REV B
4-82

FROM SHT.2

0 1 2 3 4 5 6 7

PLOT | PLOT CAL | AUX | CRT ONLY | AMPL LOG/LIN | FREQ LOG/LIN | CONT | PEAK

DB LIN | V EU | ABS REL | PER HZ | ⊗ | ⊗ | HOLD REL | ARM

SIG ENH | CHA 2K | DUAL 1K | OPT 5 | CORR | PROB | TEXT | TEXT 2

SP4 | PWR SPEC | COH | COP | DIFF | EX | TRAN | SWEEP

B | NYQ | A/B | X PROP | R/I | ∅ MAG | OPT 3 | OPT 4

SUM | START | STOP | CONT | SPS | TRAN | STO D | RCL D

AVG TIME | RMS SPEC | TF | TM | AUTO CORR | OPT 1 | OPT 2 | TEXT 4

A | OVLP | REAL | MAG | IMAG | ∅ | COMP D | EQL D

+ | − | EXP | SHIFT 1 | AVG N | DLY T→A | DLY A→B | LIN

7 | 8 | 9 | SET STORE | PNL | CUR LOC | RMS 1→2 | dB

4 | 5 | 6 | RECALL | ∫dt | d/dt | DEF AUX | V EU

1 | 2 | 3 | SHIFT 2 | COH BLNK | PLOT RATE | DSPL dB | FREQ REF

0 | • | □ | CLEAR | XPND | XPND WIDTH | DISK | ORD REF

ABC | DEF | GHI | JKL | MNO | PQR | STU | VWX

INPUT TIME | INST SPEC | X SPEC | IMP RESP | X CORR | CDF | PDF | TEXT 3

YZd | (< % | )>, | '#: | RUB | INS | ▫▪▫ | ▫▪▫

R15 784-1-R4.7K ×4 · R16 784-1-R4.7K ×4 · 4.7K ×2

+5V

TO SHT.2

IC14 81LS96 — inputs 3 17 5 15 7 13 9 11 1,19 — outputs 2 18 4 16 6 14 8 12

SCB-0 1 2 3 4 5 6 7
J1- 19 17 15 13 11 9 7 5

SWITCH COLUMN BUS

IC6 81LS97 — 12 8 14 6 3 17 5 15 7 13 9 11 1,19 — 11 9 13 7 16 15 4 5 17 18 2 3

IC20 81LS97 — 12 8 14 6 3 17 5 15 7 13 9 11 1,19 — 11 9 13 7 16 15 4 5 17 18 2 3

GPA GPB GPC GPD

IC17 74LS138 — A B C G1 G2A G2B — 1 2 3 6 4 5 — 15 12 14 13

GROUP DECODE BUS — 29,1 27,2 25,3 21,4 23,5

GPD 1 2 3 4 5

TO SH.2

J1:31 33 35 37

J1:1-43 SPARES

AGND P2-8
+5VA 4,1
+15V 9
−15V 7
+5VD 2
D GND 5
.1uF

SRB-0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
J1- 12 4 6 8 10 12 14 16 34 36 38 40 42 44 46 48

SWITCH ROW BUS

SYS RESET
J1:49

NOTE:
⊗ - NOT USED

IC28 81LS97 — 3 17 5 7 9 11 13 15 1,19 — 2 18 4 6 8 12 14 16

R11 784-1-R4.7K — 5 6 8 7 4 3
E41 CHA · E40 CHB — SOURCE S11
E39 FREQ · E38 ORDERS — FREQ/ORDERS S10
E6 HAR
SINGLE — CURSOR TYPE S2
E5 OFF
E17 HZ
CPM — FREQ READS S5
E15 ORDERS — E16

R10 784-1-R4.7K — 2 6 5 4 3 8 7
LEV∅ E42
LEV1 E43
LEV2 E44
4.7KΩ +5V E45
TRIG LEVEL (CODED SWITCH) S12 — 100-SP-8028

IC27 81LS97 — 9 11 3 5 15 7 13 17 — 8 12 2 4 16 6 14 18
FR∅ E32
FR1 E33
FR2 E34
FR3 E35
FR4 E36
FREQ RANGE (CODED SWITCH) S9 — 100-SP-8027
E37

R12 784-1-R4.7K — 8 7 3 2 4 5 6
BAMPL∅ E56
BAMPL1 E57
BAMPL2 E58
MAX AMP (CODED SWITCH) S13 — 100-SP-8026
E59

IC31 81LS97 — 13 7 15 3 17 5 9 11 1,19 — 14 6 16 2 18 4 8 12

BINV E52 INV
NOR — S15
B ZERO E51 ZERO
B TEST E50 TEST
AC — S14
BDC E48 DC — E49

R9 784-1-R4.7K — 5 4 3 2 8 7 6
AAMPL∅ E18
AAMPL1 E19
AAMPL2 E20
MAX AMP (CODED SWITCH) S6 — 100-SP-8026
E21

IC26 81LS97 — 13 9 11 3 17 5 15 7 — 14 8 12 2 18 4 16 6

AINV E26 INV
NOR — S8
A ZERO E24 ZERO
A TEST E23 TEST
AC — S7
ADC E22 DC — E25

CHB
CHA

OPTION -8

| | |
|---|---|
| OPT 1 | CM |
| OPT 2 | IFFT |
| OPT 3 | STORE C |
| OPT 4 | VIEW C |

OPTION -3

| | |
|---|---|
| OPT 5 | OCT |

MODEL 660B (SN 550 - )
FRONT PANEL
100-SC-8708
SHEET 1 of 2 REV B
4-82

SWITCH COLUMN BUS FROM SHT.1

IC1 25LS08: 10 dB/LIN, 7 V/EU, 15 ABS/REL, 2 PER HZ → R2 (899-1-R270)

IC2 25LS07: 7 LIN/LOG (AMPL), 10 LIN/LOG (FREQ), 2 PLOT, 15 PLOT CAL, 5 AUX → R2 (899-1-R270)

IC7 25LS08: 7 OPT 5, 10 SIG.ENH, 2 CHA 2K, 15 1K DUAL, 15 CORR, 2 PROB, 10 REMOTE, 7 TEXT
IC32 25LS08 → R3 (899-1-R270)

IC18 25LS08: 15 TEXT 3, 10 PDF, 2 XCORR, 7 CDF → R4, R3 (899-1-R270)

IC19 25LS08: 10 OPT 1, 7 AUTO CORR, 2 OPT 2, 15 TEXT 4 → R4 (899-1-R270)

IC8 25LS07: 7 INPT TIME, 10 INST. SPEC, 5 X SPEC, 12 AVG. TIME, 2 RMS SPEC, 15 TF → R5 (899-1-R270)

IC9 25LS08: 2 IMP RESP, 10 COP, 15 TEXT 2, 7 TM, 10 SP4, 2 PWR SPEC, 15 COH → R4, R3, R4, R5 (899-1-R270)
IC33 25LS08

IC10 25LS08: 10 SUM, 7 DIFF, 2 EX, 15 PEAK → R5, R6 (899-1-R270)

IC11 25LS08: 15 SWEEP, 10 START, 2 SPS, 7 TRAN → R6, R5, R6 (899-1-R270)

IC12 25LS07: 12 A, 2 REAL, 15 MAG, 5 B, 10 IMAG, 7 Ø → R7 (899-1-R270)

IC13 25LS07: 5 A/B, 7 R/I, 10 Ø/MAG, 15 X PROP, 2 NYQ, 12 OVLP → R7 (899-1-R270)

GROUP DECODE BUS FROM SHT.1

IC16 74LS138: A, B, C, G1, G2B, G2A (+5V); Y0–Y7

IC15 74LS138: A, B, C, G2B, G2A, G1; Y0–Y7

+5VA J5 POWER TO OPT.

J2 POWER: +5VD, DGND, +15V, -15V, AGND

IC21 25LS07: 12 OPT 3, 7 OPT 4, 15 EQL D, 10 COMP D, 2 RCL D → R6, R7 (899-1-R270)

IC29 25LS08: 10 CONT, 15 TRAN, 7 ARM, 2 HOLD/REL → R8 (899-1-R270)

IC22 25LS07: 10 A B C, 7 Y Z d, 12 DEF, 5 ( < %, 2 GHI, 15 ) > , → R6, R17 (899-1-R270)

IC23 25LS07: 7 J K L, 10 ' # :, 5 M N O, 12 R U B, 15 P Q R, 2 I N S → R17 (899-1-R270)

IC24 25LS08: 10 S T U, 7 □■□, 15 V W X, 2 □□■ → R17 (899-1-R270)

J1:
20 Ø LOAD — 270Ω — +5V
22 CHA 1/2, 24 1/4, 26 1/8, 28 1/16 → R2 (899-1-R270)
J1:
39 Ø LOAD, 41 CHB 1/2, 43 1/4, 45 1/8, 47 1/16 → R8 (899-1-R270)
POWER ON E61 E60 R4 ← 899-1-R270

(JI-30) — 1MΩ — E29 — CHA DCADJ R13 20KΩ — E31 +15V, E30 -15V

(JI-50) — 1MΩ — E53 — CHB DCADJ R14 20KΩ — E54 +15V, E55 -15V

(F.P. BNC) ORDERS → EG2 EG3 EG4 EG5

B INPUT (F.P.BNC) → E46 E47

+15V, -15V

J1 INPUT ATTN CHB → J4 → IC30 LM310 (IN914, 100Ω, 5.6MΩ, 2.5V, K2, IN914 → +5V)

ORDERS (F.P.BNC) → J2 INPUT ATTN CHA J1 → J3

BDCEN-R (J1-32)

A INPUT (F.P.BNC) → E27 E28

SAME AS CHB

IC25

K1

-15V, +15V

ADCEN-R (J1-18)

IC5 (1,19)

IC3 74LS279: R1 899-1-R4.7K, LEFT E1 E2 E3 E4 → CURSOR POSITION S1, RIGHT

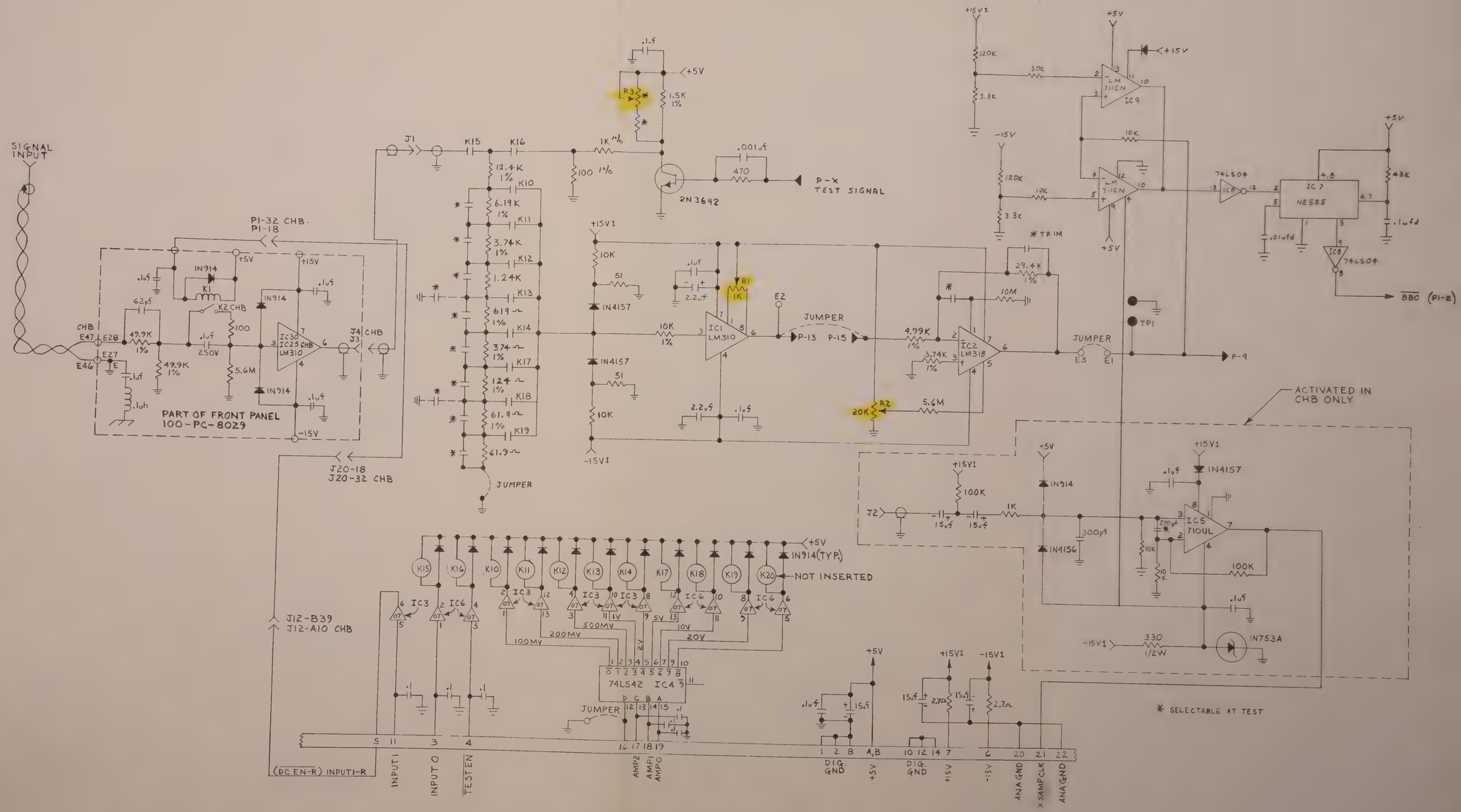
IC4 74LS279: R1 899-1-R4.7K, UP E5 E6 E7 E8 → UPPER S3, DOWN; UP E9 E10 E11 E12 → LOWER S4, DOWN E16 → GAIN

0 1 2 3 4 5 6 7 → 1/2 SWITCH ROW BUSS TO SHT1

GPD FROM SHT1

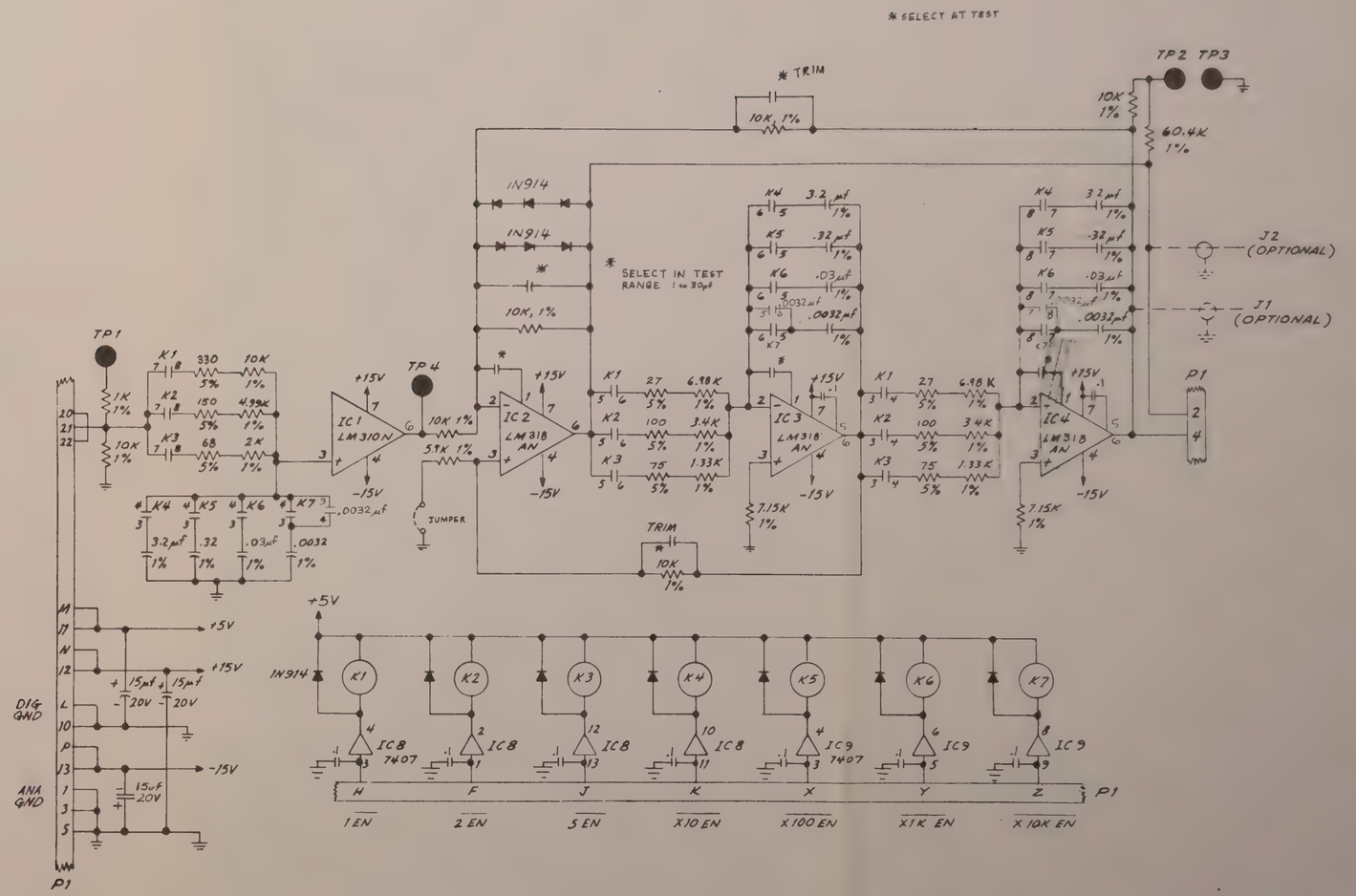
NOTE:
* = SELECT AT TEST

MODEL 660B (SN 550 -
FRONT PANEL
100-SC-8708
SHEET 2 of 2 REV B
4-82

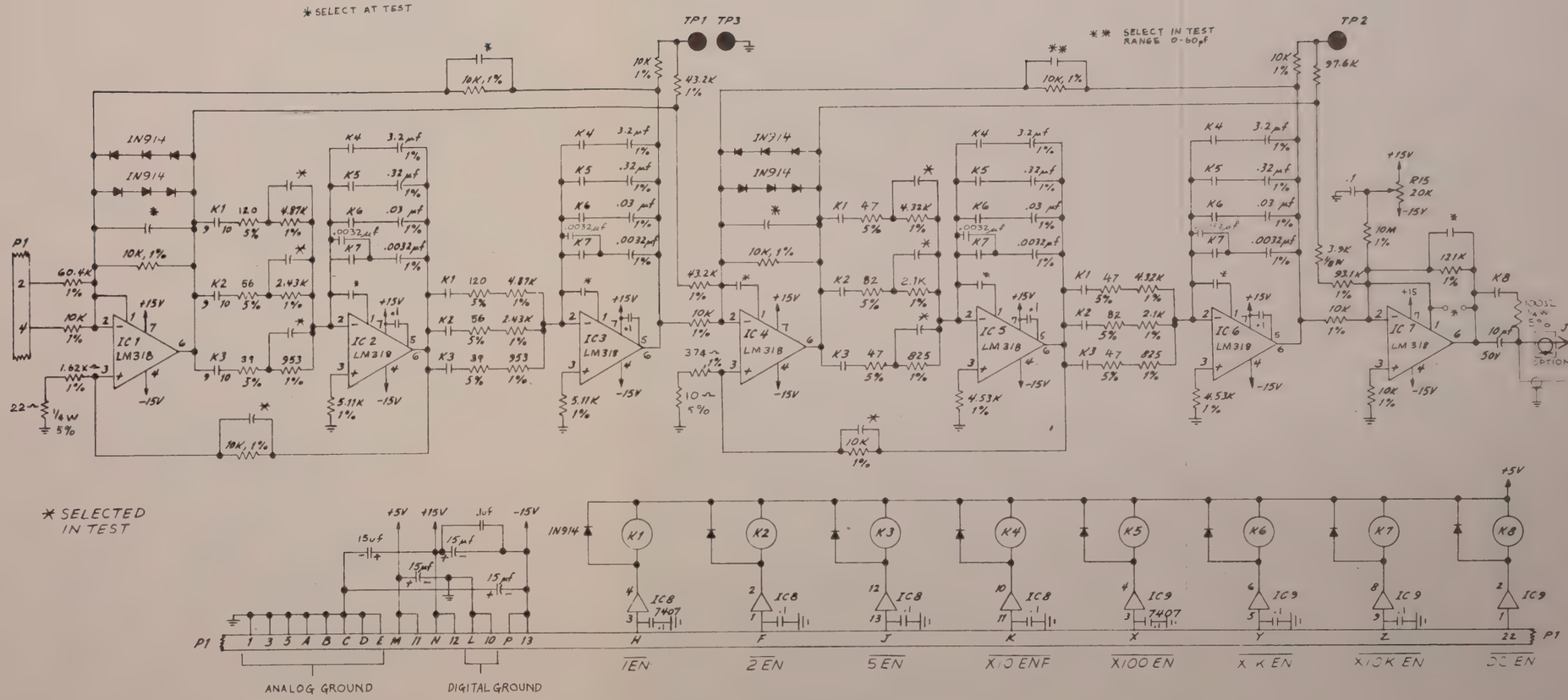



MODEL 660B (SN 550 -
INPUT ATTENUATOR
100-SC-8064
SHEET 1 of 1

REV E
4-82




MODEL 660B (SN 550 - )
FILTER NUMBER 1
100-SC-8598
SHEET 1 of 1 REV B
4-82







MODEL 660B (SN 550 - )
FILTER NUMBER 2
100-SC-8614
SHEET 1 of 1 REV B
4-82

## OFFSET AMPLIFIER

## SAMPLE & HOLD

## OVERLOAD DETECTION

## SYNCHONIZER

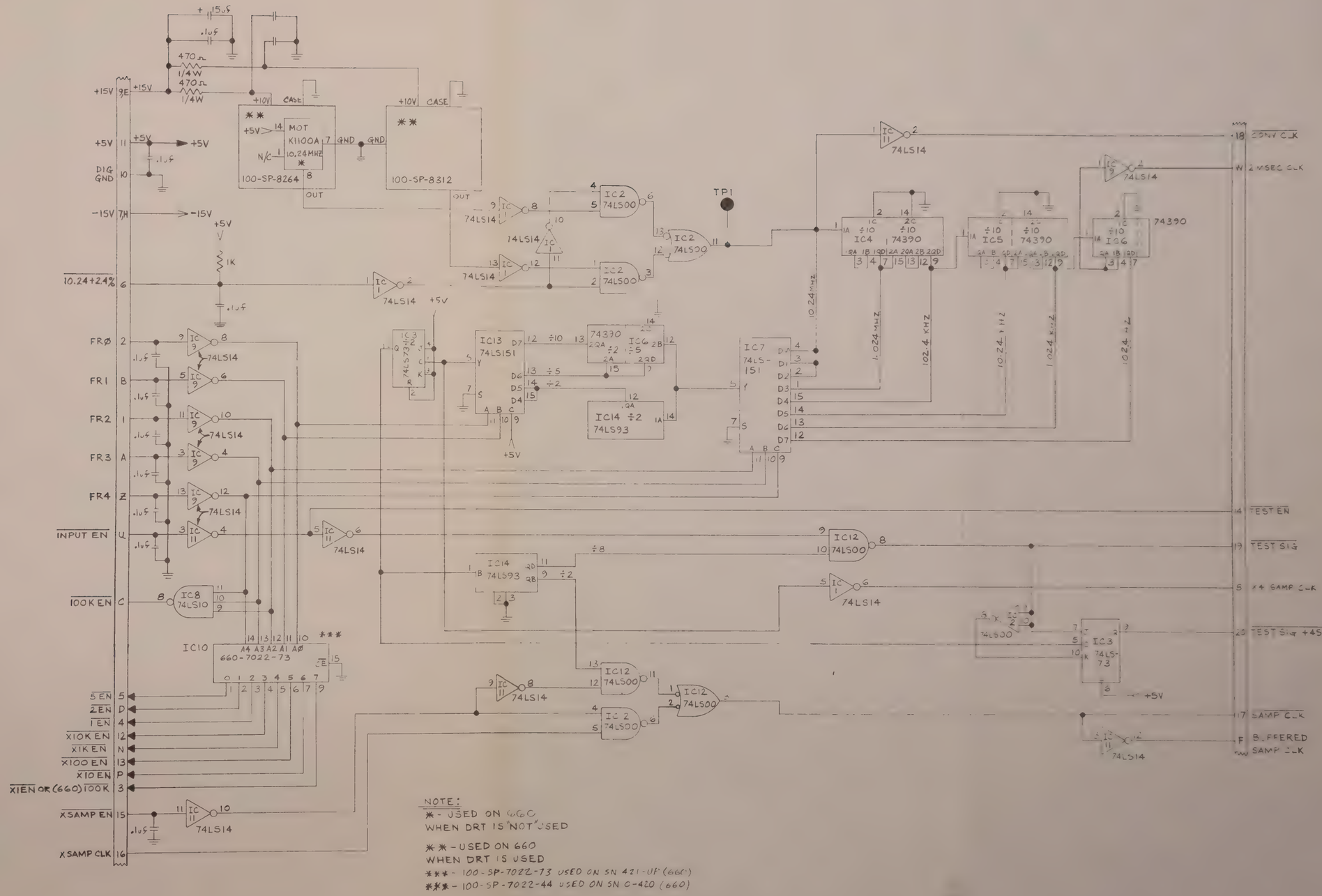
NOTE:
1. JUMPERS
DATEL EH1283 1-2, 4-5

2. 100-SC-8304C TO BE USED WITH 100-PC-8227

3. * = SELECTABLE AT TEST

MODEL 660B (SN 550 - )
A/D CONVERTER
100-SC-8304
SHEET 1 of 1

REV B
4-82




NOTE:
- ✱ - USED ON 660 WHEN DRT IS "NOT" USED
- ✱✱ - USED ON 660 WHEN DRT IS USED
- ✱✱✱ - 100-SP-7022-73 USED ON SN 421-UP (660)
- ✱✱✱ - 100-SP-7022-44 USED ON SN 0-420 (660)

MODEL 660B (SN 550 - )
SAMPLING CONTROL
100-SC-8313
SHEET 1 of 1 REV B
4-82

SPARES:

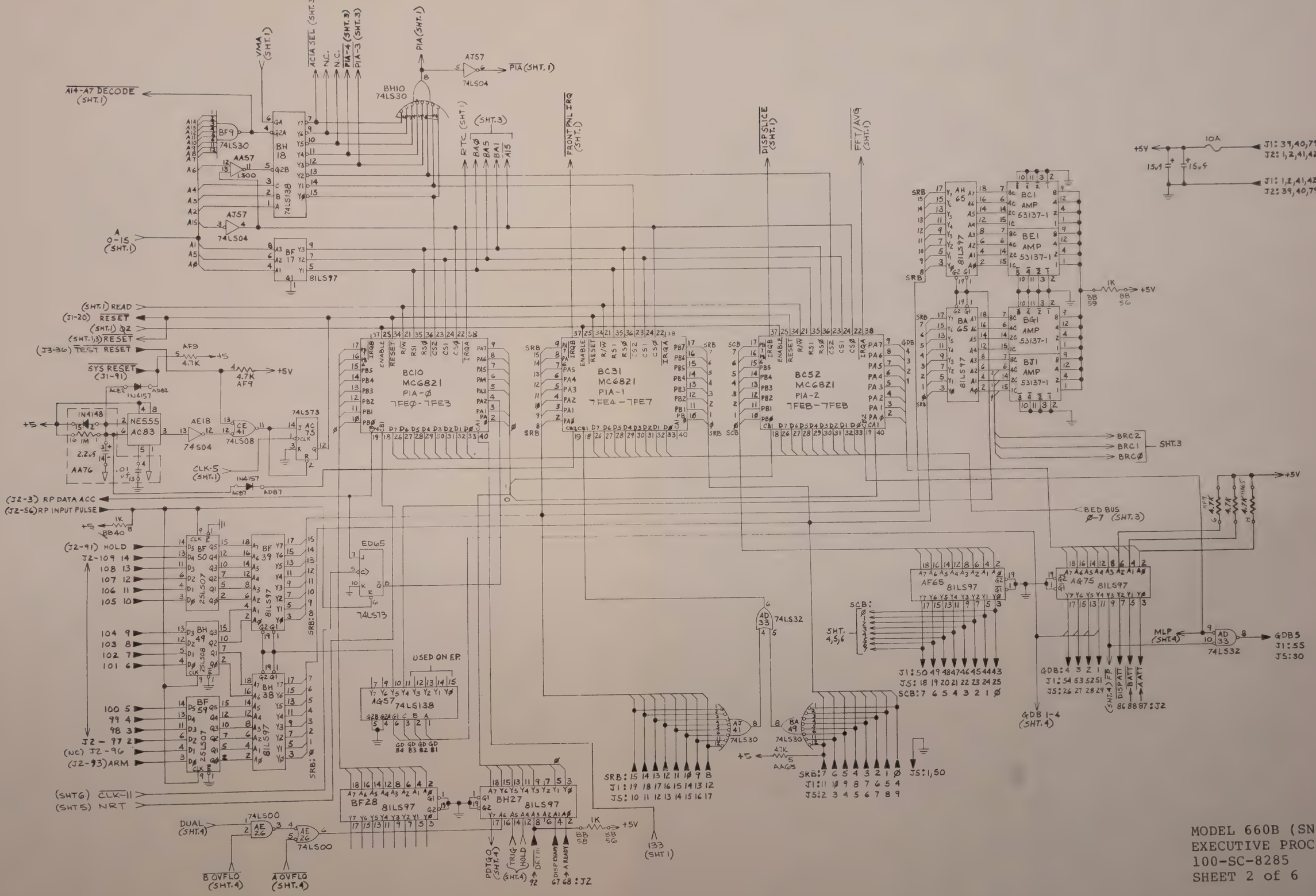
74LS73 - DA81 - 1/2
74LS08 - CC10 - 1/2
7407 - DA90 - 5/6
74LS86 - CG41 - 2/4
81LS97 - BF17 - 1/8
MC1488 - CF88 - 2/4
MC1489A - CG81 - 1/4

74LS04 - EB90 - 1/6
74LS14 - AC90 - 2/6
1K - BB56 - 4/7
4.7K - CA48 - 5/7
4.7K - EE89 - 6/7

74LS02 - BB90 - 1/4
74LS27 - AB33 - 2/3
9612 - AH85 - 1/2
74LS00 CK-1 - 3/4
74LS73 - CH74 - 1/2
74LS73 - ED65 - 1/2

SPARE I/O'S
J1:
J2:
J3: 35, 37-49

MODEL 660B (SN 550 - )
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 1 of 6 REV B
4-82



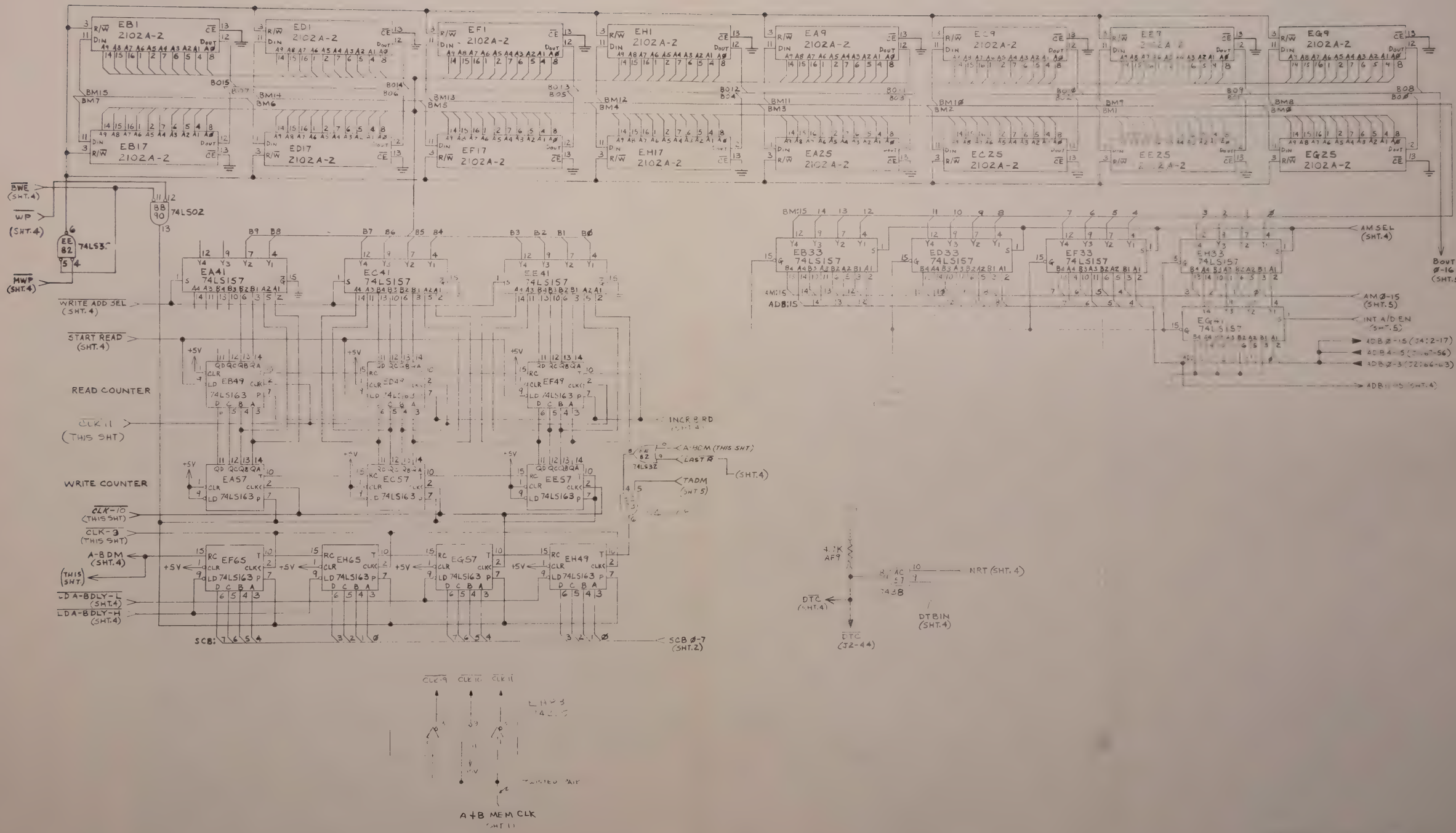

MODEL 660B (SN 550 -
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 2 of 6 REV B
4-82

| SWITCH SETTING | C | B | A | RATE(BPS) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 110 |
| 1 | 0 | 0 | 1 | 150 |
| 2 | 0 | 1 | 0 | 300 |
| 3 | 0 | 1 | 1 | 600 |
| 4 | 1 | 0 | 0 | 1200 |
| 5 | 1 | 0 | 1 | 2400 |
| 6 | 1 | 1 | 0 | 4800 |
| 7 | 1 | 1 | 1 | 9600 |

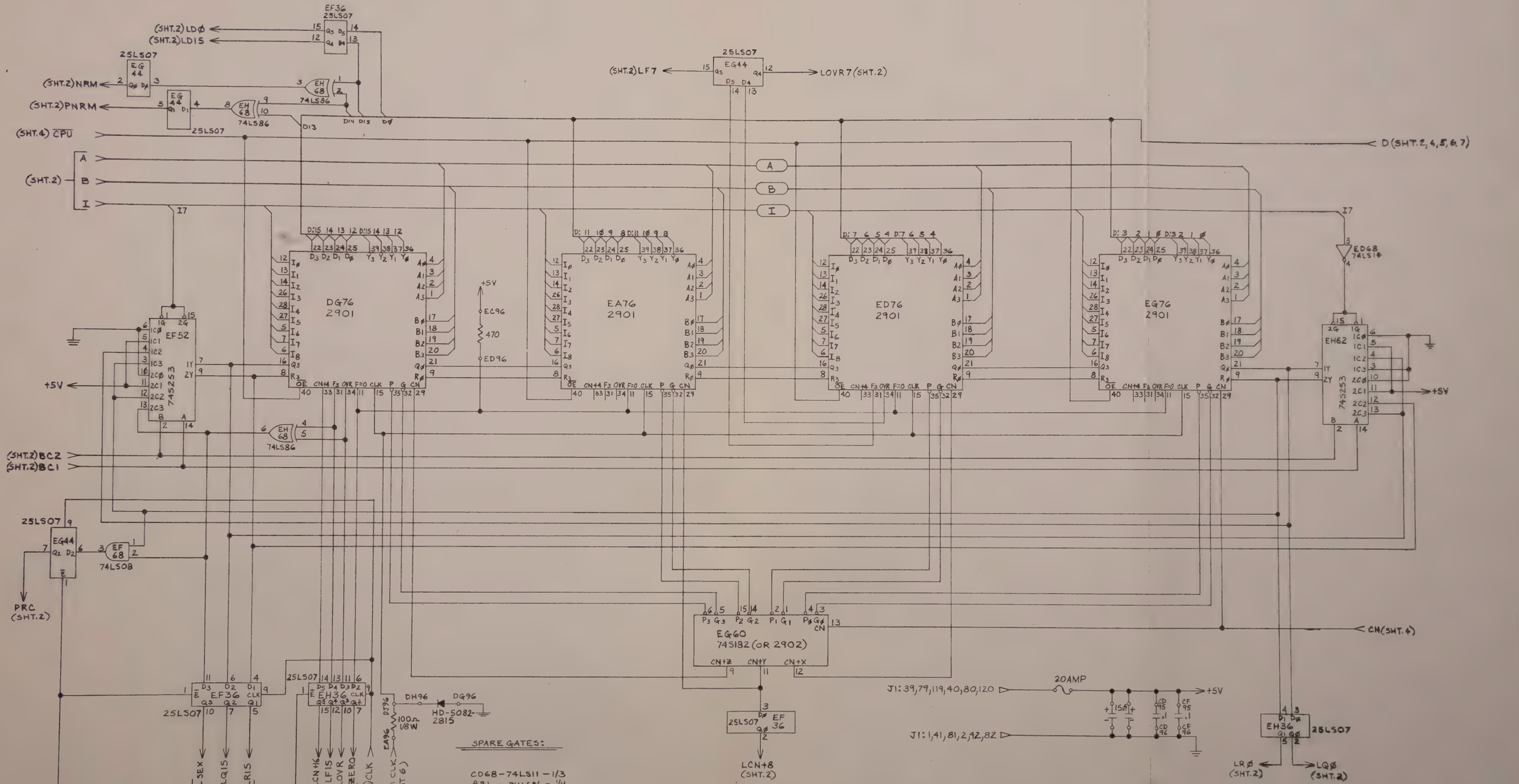
MODEL 660B (SN 550 - )
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 3 of 6 REV B
4-82

MODEL 660B (SN 550 - )
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 4 of 6 REV B
4-82

MODEL 660B (SN 550 -
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 5 of 6 REV B
4-82




MODEL 660B (SN 550 - )
EXECUTIVE PROCESSOR
100-SC-8285
SHEET 6 of 6 REV B
4-82




SPARE GATES:

CD68 - 74LS11 - 1/3
AB1 - 74LS86 - 1/4
ED68 - 74LS14 - 2/6
AD19 - 1K - 3/13
AA86 - 4.7K - 4/7
DC68 - 74S08 - 1/4
AG60 - 74LS00 - 2/4
DF76 - 4.7K - 4/7
AB08 - 74LS73 - 1/2
BE68 - 74LS32 - 3/4
AB36 - 25LS07 - 4/6
CH68 - 74LS04 - 1/6
AD36 - 7438 - 1/4

EH68 - 74LS86 - 1/4

SPARE IO'S

J1: 29-33, 50, 60, 95-99, 91, 46, 93, 94, 84, 85, 47, 61, 62
J5: ALL
J4: 19,

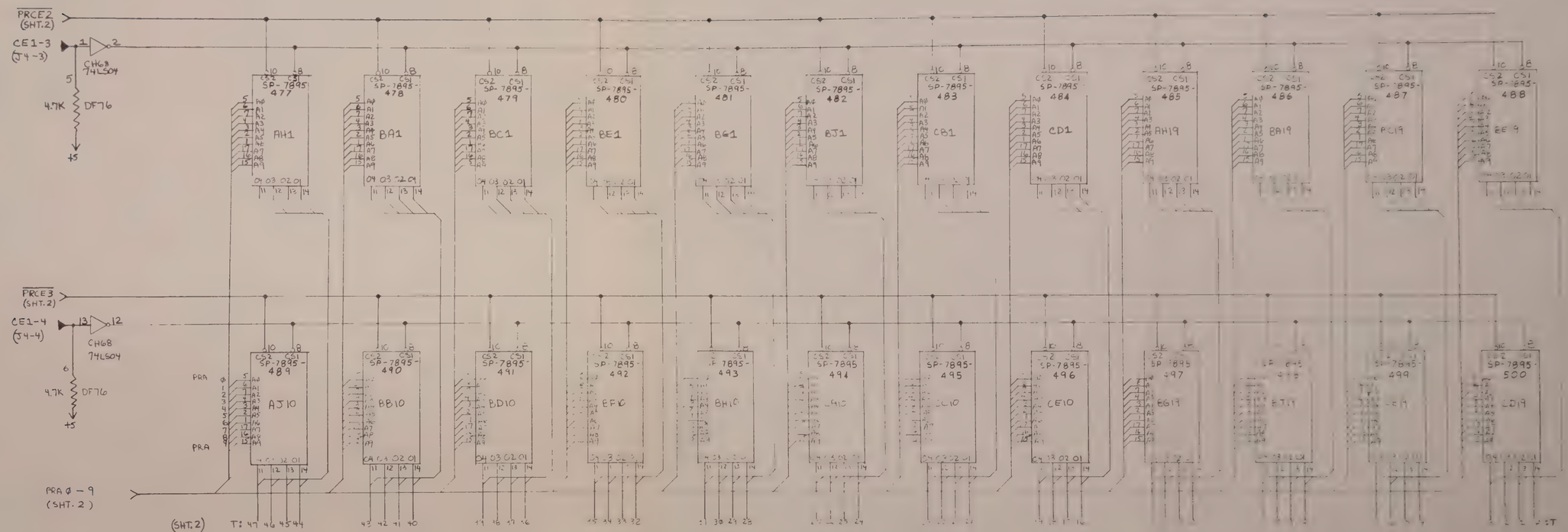
MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 1 of 7

REV B
4-82

J4-49
J4-50
J4-1
J4-2
J3-49
J3-50
+5V
FOR LOT 8305 & UP 74LS14
AB53 74LS04 2,3 4,5 6,13 12,11 10,9
AE45 74LS04 2,3 4,5 6,13 12,11 10,9
AF D2 D3 3Q 25LS07 Q2 Q3
D:11 10 9 8
D:7 6 5 4
D:3 2 1 Ø
(SHT. 1)
TEST COND. (SH 4-37)
INCR COUNT (SHT. 4)
FLAG1 (SHT. 2) FLAG1 (J4-39)
MEM FLAG1 (SHT. 4)
FLAGØ (SHT. 2)
FLAG8 (SHT. 6)
MEM FLAGØ (SHT. 4)
74LS74
74LS08
4.7K AA86
PRCE2 (SHT. 3)
PRCE3 (SHT. 3)
J4-19
CE2-2 (J4-6)
CE2-1 (J4-5)
TESTADDEN (J4-20)
TESTADDEN (J4-48)
SLICE RESET (J1-49)
2911 CLK (SHT 6)
PRA:Ø-9 (J4: 7-16)
PRA11 (J4-42)
PRA10 (SHT. 3) (J4-17)
DRAØ-10 (SHT. 3)
BANK 1
BANK 2
TEST 24-31 (J3:25-32) (SH. 3)
TEST 32-39 (J3:33-40) (SH. 3)
TEST 40-47 (J3:41-48) (SH. 3)
CLK (SHT. 6)
DATA SEL
SEQ. ADD SOURCE Ø
SEQ ADD SOURCE 1
INCREMENT
FILE ENABLE
PUSH/POP
REGISTER ENABLE
SC: 3 2 1 Ø
TCS: Ø 1 2
TCS: 5 4 3
PGM (J4-47)
TRAP (J1-62)
AVGA (J1-64)
PNRM (SHT. 1)
FLAG1 (SHT. 2)
FLAGØ (SHT. 2)
FRC (SHT. 1)
ATTEN (J1-65)
CLK-1
(SHT. 1) F7
LOVR7 (SHT. 1)
N.C.
DISPADV (J1-63)
SMF (SHT. 5)
MRP (SHT. 4)
DTGO (J1-66)
EXDTGO J1-44
DTC (SHT. 5)
NRM
LSEX
LCN+8
LQØ
LRØ
LQ15
LR15
LF15
SHT. 1
COUNTER CARRY (SHT. 4)
MBL (SHT. 6)
LD15
LDØ
LCN+16
LOVR
LZERO
+5V
TEST 16-23 (J3:17-24) (SHT. 3)
TEST 8-15 (J3:9-16)
TEST Ø-7 (J3:1-8)
SHT. 3
220Ω (TYP)
330Ω
OPTIONAL ON ALL 48 LINES
+5V J3 (50)
SEPERATE ASSEMBLY CONNECTS TO J3 ON COMPONENT SIDE.
I (SHT. 1)
BC (SHT. 1, 4)
BS (SHT. 4)
BD (SHT. 4)
A (SHT. 1)
B (SHT. 1)
TCS: Ø-5 (SHT. 7)
JA (SHT. 7)
SEPERATE ASSEMBLY CONNECTS TO J3 ON COMPONENT SIDE.
510Ω
(PA) (SHT 5)
NC

MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 2 of 7

REV B
4-82




MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 3 of 7 REV B
4-82

MEMORY DATA IN

MEMORY DATA OUT

UPPER

LOWER

UPPER

LOWER

MDB:0-7 (J1:4-11)

MDB:7 6 5 4 3 2

MDB:1 0 7 6 5 4

MDB:3 2 1 0

MDB:7 6 5 4 3 2 1 0

MDB:7 6 5 4 3 2 1 0

DTB:15 14 13 12 11 10 9 8

DTB:7 6 5 4 3 2 1 0

DTB:15 14 13 12 11 10 9 8

DTB:7 6 5 4 3 2 1 0

DTBX IN (J1-90)

4.7K AC5% 1/8W AB36

+5V

DTBX OUT (J1-92)

XDTB 0-15 (J1:67-78, 86-89)

DTB 0-15 (J1:12-27) (J4:21-36)

E DD 25LS07 CLK

E DF 25LS07 CLK

E 25LS08 DH44 CLK

CF 81LS97

CG 81LS97

AB 81LS97

AF 81LS97

AD 81LS97

AH 81LS97

CH 81LS97

CJ 81LS97

E DC 25LS07 CLK

E DE 25LS07 CLK

E 25LS08 DG36 CLK

CD 81LS97

CE 81LS97

CB 81LS97

CC 81LS97

CA 81LS97

XDTB:15 14 13 12 11 10 9 8

XDTB:7 6 5 4 3 2 1 0

XDTB:15 14 13 12 11 10 9 8

XDTB:7 6 5 4 3 2 1 0

D (SHT.1)

D:15 14 13 12 11 10 9 8

D:7 6 5 4 3 2 1 0

D:15 14 13 12 11 10

D:9 8 7 6 5 4

D:3 2 1 0

D:15 14 13 12 11 10 9 8

D:7 6 5 4 3 2 1 0

D:15 14 13 12 11 10 9 8

D:7 6 5 4 3 2 1 0

D:15 14 13 12 11 10 9 8

CLK-3 (SHT.6)

TOP ZERO

25LS07 AF36

MRP (SHT.2)

CLK-TP (SHT.6)

25LS08

MDDR:0-15 (J1:102-117)

MDDR:15

MDDR:7

DB 75 81LS97

DE 25LS07

DA 85 81LS97

DC 25LS07

AG 60

74LS00

74LS08

EF 68

BG 68 LS 10

AG 60 LS 00

EF 68

74LS08

7438

CB 68

AH68 PIN 2 (SHT. ) I-89

ED68 74LS14

DA 68

AA1 4.7K

+5V

CLK-A (SHT. 6)

DTB CONTR-B (SHT. 5)

READ

WRITE

LOAD MDB LATCH

WRITE HI

WRITE LOW

74LS73 BJ68 J CLK K

74LS11

CD 68

BE 68

EDGB 74LS4

74LS73 DE68

74LS32 AE 60

74LS73 CF68

DC 68 74S08

MDB REQ.

8556 CJ28

8556 DB28

AB68 74LS73

EG44 25LS07

AD36 7438

COUNTER CARRY (SHT. 2)

BDEN (J1:62)

CLK-1 (SHT.6)

INCR COUNT (SHT. 2)

LCOUNT

AB36

PRIORITY-IN (J1-48)

25LS07

MDDRR (J4-45)

AA1 4.7K

+5V

MBL (SHT 6)

AA86 4.7K

DEN (J4-46)

BS (SHT.2)

SP-7022-29

SP-7022-30

MDLB

MDUB

200pf

CC96

CC95

10Ω 1/8W

CC95

74LS08

LOAD ADDR REQ CYCLE

B7 B6 B5 B4 B3 B2 B1 B0

CE DH 60 SP-7022-33

A4 A3 A2 A1 A0

ED68 74LS14

AB1 74LS86

+5V

EXT

SP-7022-31

SP-7022-32

BD (SHT.2)

BD:3 2 1 0

EXT D BUSEN (J4-40)

(SHT.7) CR

(SHT.5) SLICE MEM

(SHT.1) CPU

(SHT 6) CROM 2

(SHT. 7) JADDR

(SHT.5) SPR

(SHT.6) CROM 1

(SHT.6) PLW

(SHT.6) PHW

(SHT.5) DTBIN

UPPER (J4-44)

LOWER (J4-43)

(SHT.1) CN

LCN+16 (SHT.1)

BC 2 1 0

SHT.2

DTB OUT (SHT.5)

(J1-83) R/W

(J1-118) VMA

WRITE EN (J1-28)

PRIORITYOUT (J1-101)

(SHT.6) CLK-2

(SHT.7) LCR

(SHT.5) LSMD

(SHT.5) LSMA

N.C.

(SHT.5) SPW

(SHT.2) MEMFLAG 1

(SHT.2) MEMFLAG 0

(SHT.6) CRA

N.C.

N.C.

N.C.

(SHT.6) LMB

(SHT.6) LMA

MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 4 of 7 REV B
4-82

MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 5 of 7

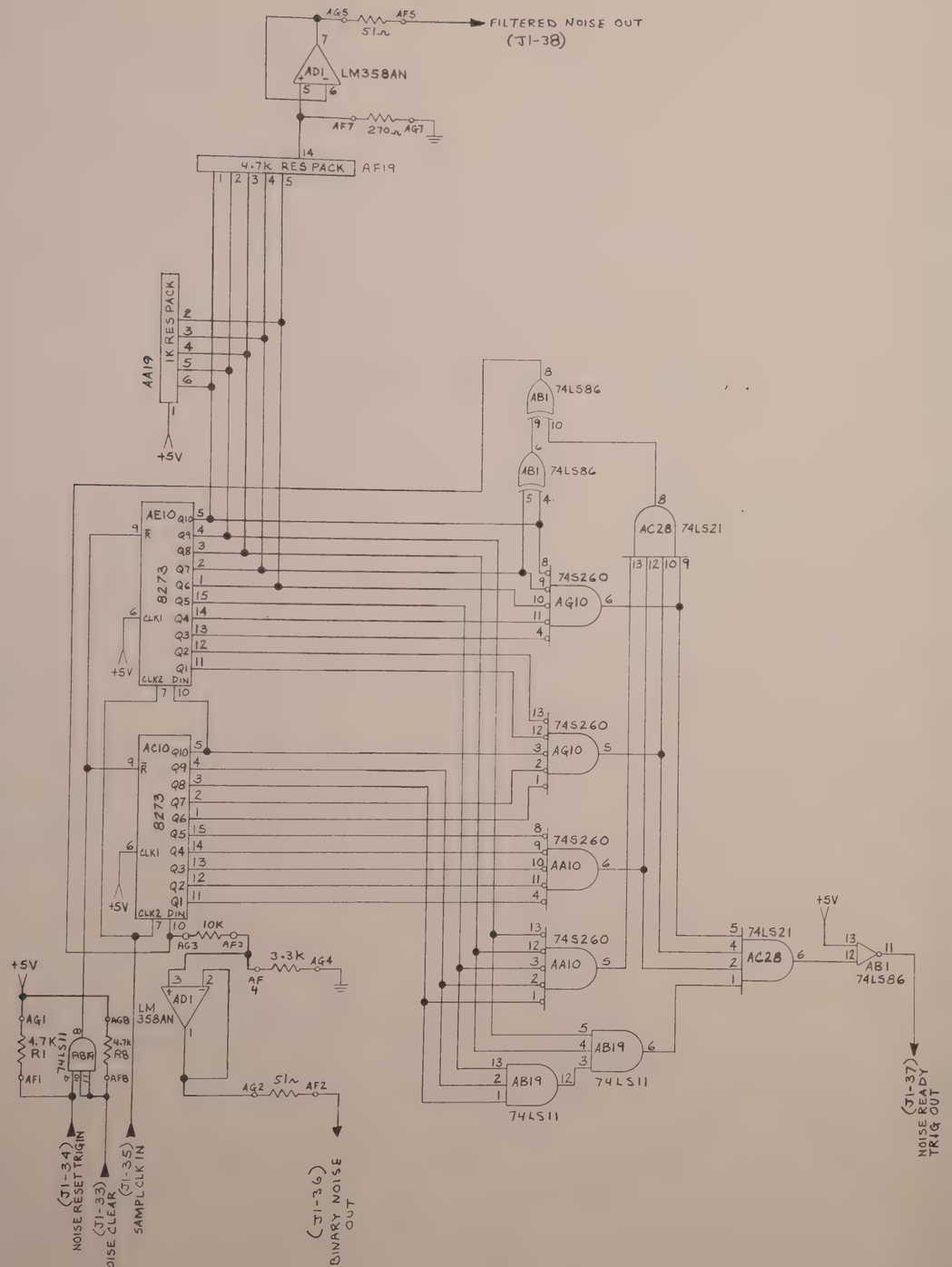
REV B
4-82

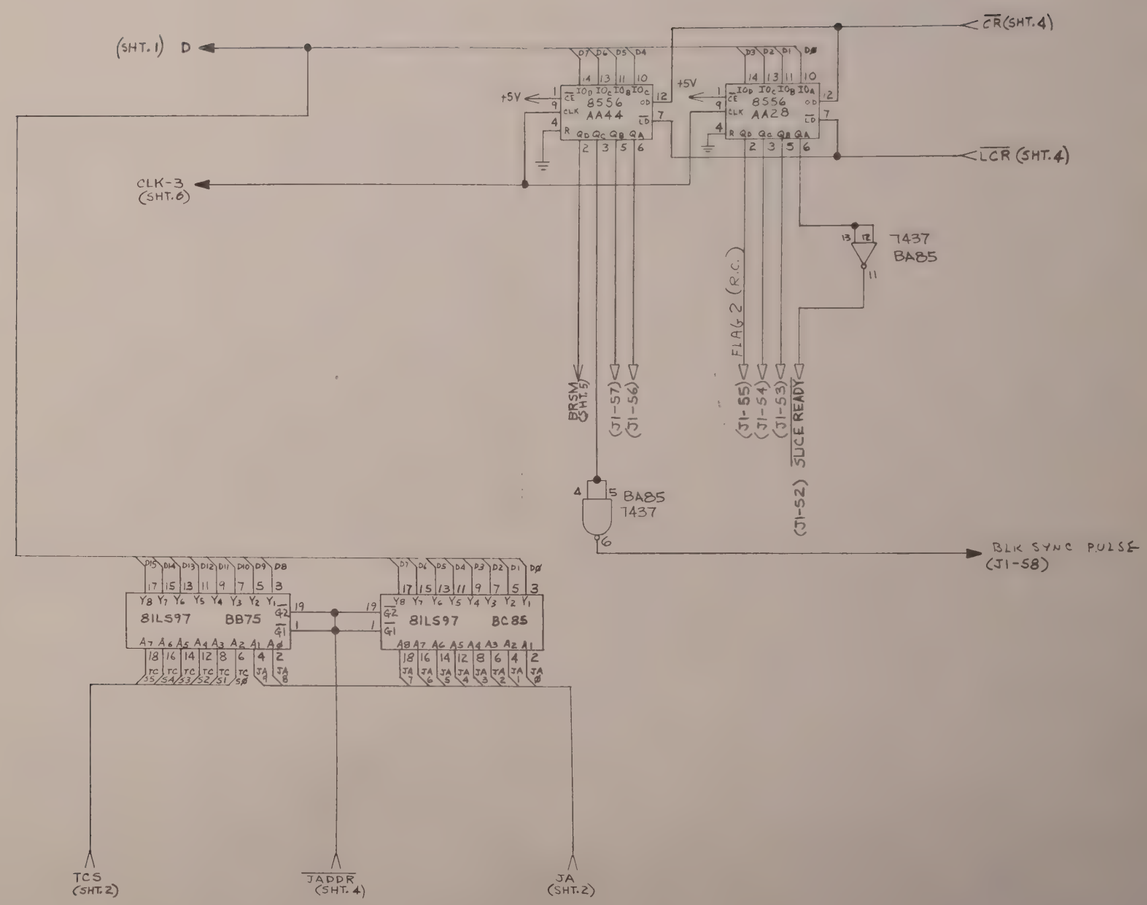
CLK-4 (THIS SHT.)
MBL (SHT. 2)
CLK-1 (SHT. 4)
LMB (SHT. 4)
CLK-2 (THIS SHT)
CLK-2 (THIS SHT)
CROM2 (SHT. 4)
CROM1 (SHT. 4)
PHW (SHT. 4)
PLW (SHT. 4)
D (SHT. 1,2,4,5,7)
LMA (SHT. 4)
CLK-4 (SHT. 4)
CLK-TP (SHT. 4)
CLK (THIS SHT.)
CLK-2 (THIS SHT.)
CRA (SHT. 4)
CLK (SHT 1,2)
2901 CLK (SHT 1)
CLK-3 (SHT. 7) (SHT. 4)
THIS (SHT)
CLK-1 (SHT. 4,5)
2911 CLK (SHT 2)
CLK (SHT. 2,5)
TESTCLK (34-41)
CLK-IN (J1-3)
SINGSTEP EN
(J4-18)
+5V
DH-G36
AH-G44

25LS07 AB36
AD53 74LS73
AA60 74LS04
BG68 74LS10
74LS163 BB44
AD68 74LS73
BD75 AM25LS22
BE85 AM25LS22
BF75 AM25LS22
BG85 AM25LS22
BA36 25LS08
BB28 25LS07
AJ28 25LS07
AG28 25LS07
AG44 25LS07
AJ44 AM25LS14
AH36 AM25LS14
CF1 SP-8321-92
CH1 SP-8321-93
DA1 SP-8321-94
CG10 SP-8321-95
CJ10 SP-8321-96
CF19 SP-8321-97
CH19 SP-8321-98
DA19 SP-8321-99
AF52 74265
AH52 74265
AE60 74LS32
AC60 74S04
BA88 7437
AA91 4.7k
.1uF
* SELECT AT TEST

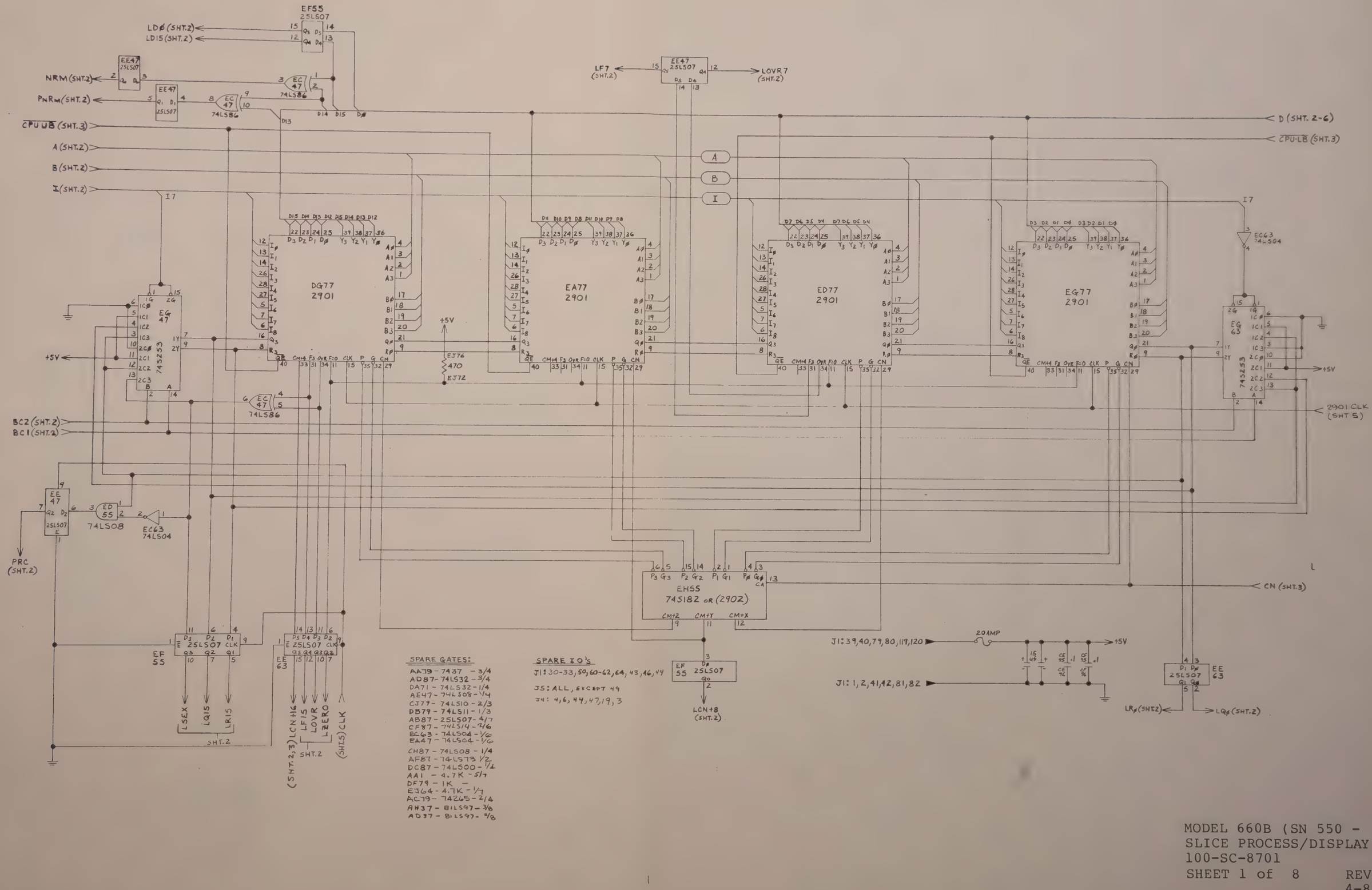
MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 6 of 7

REV B
4-82




MODEL 660B (SN 550 - )
SLICE PROCESSOR/
FFT AVERAGER
100-SC-8626
SHEET 7 of 7 REV B
4-82




SPARE GATES:

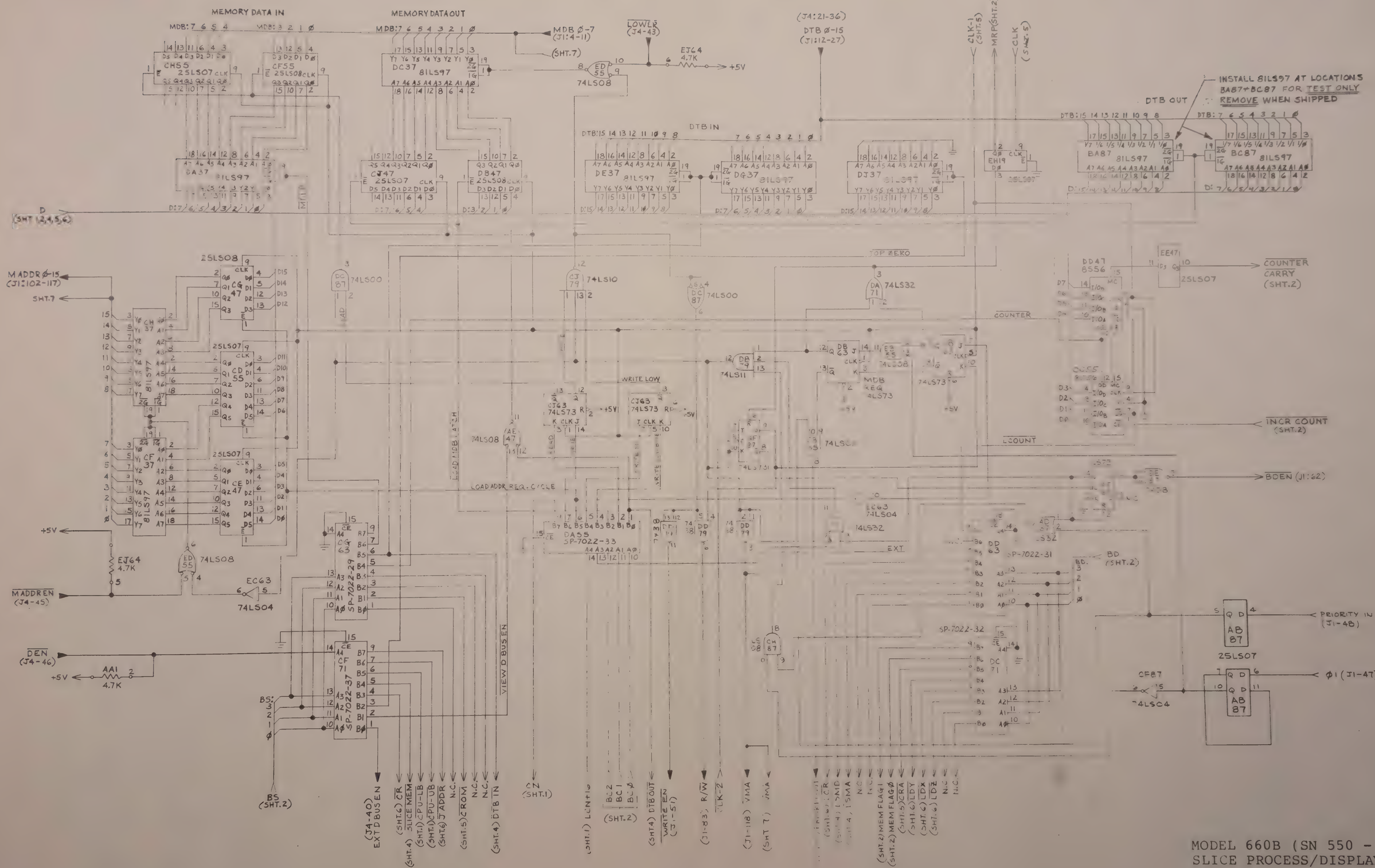
AA79 - 7437 - 3/4
AD87 - 74LS32 - 3/4
DA71 - 74LS32 - 1/4
AE47 - 74LS08 - 1/4
CJ79 - 74LS10 - 2/3
DB79 - 74LS11 - 1/3
AB87 - 25LS07 - 4/7
CF87 - 74LS14 - 2/6
EG63 - 74LS04 - 1/6
EA47 - 74LS04 - 1/6
CH87 - 74LS08 - 1/4
AF87 - 74LS73 1/2
DC87 - 74LS00 - 1/4
AA1 - 4.7K - 5/7
DF79 - 1K - -
EJ64 - 4.7K - 1/7
AC79 - 74265 - 2/4
AH37 - 81LS97 - 3/8
AD37 - 81LS97 - 3/8

SPARE I O's

J1: 30-33, 50, 60-62, 64, 43, 46, 44
J5: ALL, EXCEPT 49
J4: 4, 6, 44, 47, 19, 3

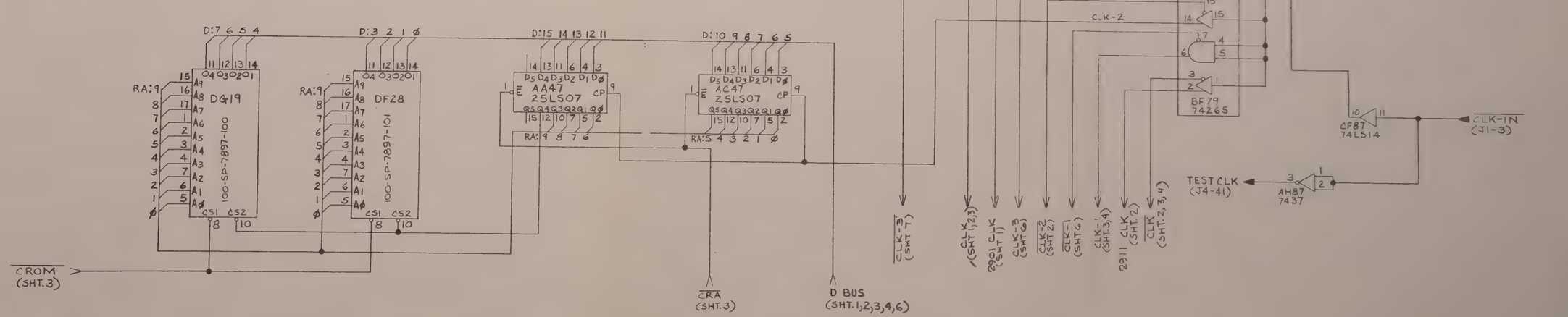
MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 1 of 8 REV B
4-82

MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 2 of 8 REV B
4-82

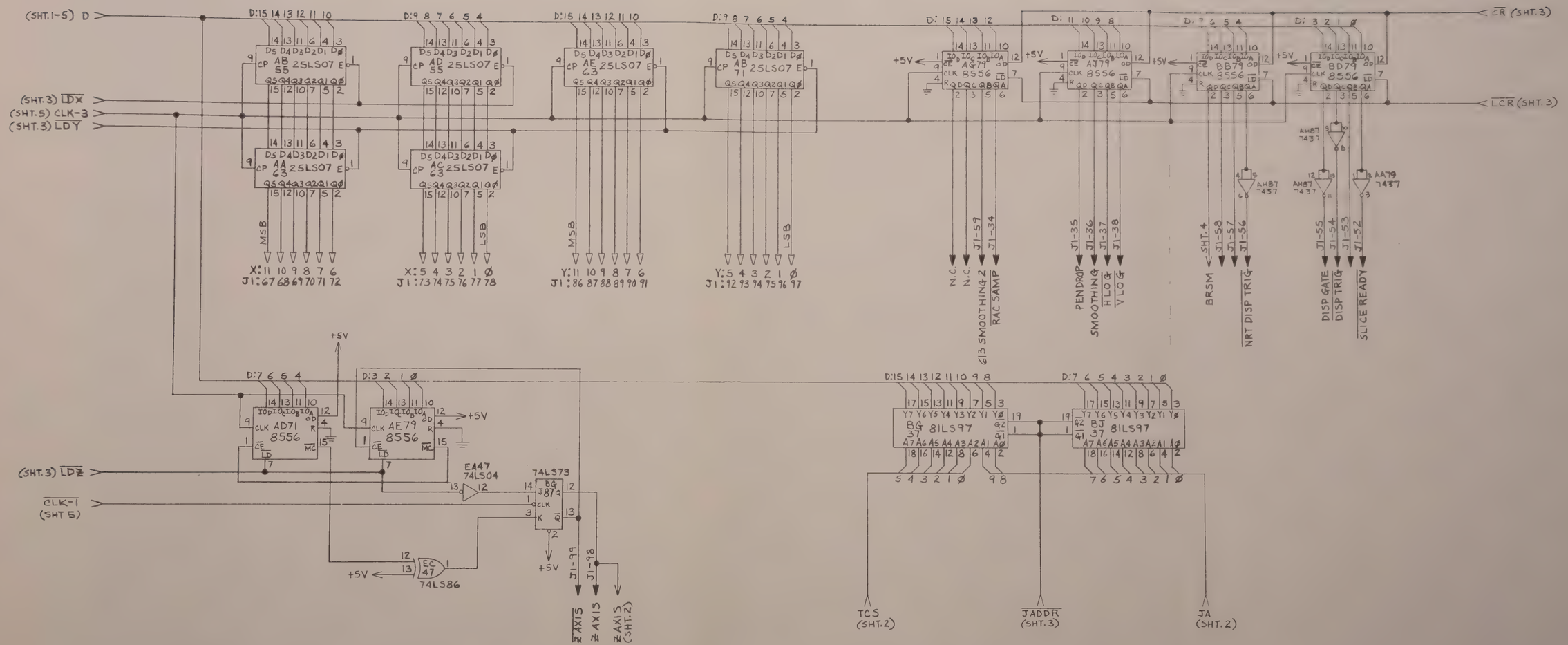



MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 3 of 8 REV B
4-82

MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 4 of 8 REV B
4-82




MODEL 660B (SN 550 -
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 5 of 8 REV
4-82




MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 6 of 8 REV B
4-82

CS1-3
CS1-2
CS1-1
CS1-Ø
(SHT.8)

CF87 74LS17
B687 74LS13

VMA (SHT 3)
CLK-3 (SHT 5)

ZAØ-9

MADDR:12 11 10 9 MADDR: 8

MADDR: 7 6 5 4 3 2 1 MADDR: Ø

8K-6 (J1-28)
8K-7 (J1-29)
8K-4 (J1-85)
8K-5 (J1-84)

ZA: 7 6 5 4 3 2 1 Ø

QA: 7 6 5 4 3 2 1 Ø

QAØ-9 (SHT.8)

A-CS2-1
A-CS2-2
(SHT.7&8)

CS1: 7 6 5 4 (SHT.8)

ZDØ-7 (SHT.8)

MDB:

A-CS2-2 (THIS SHT.)

74LS08

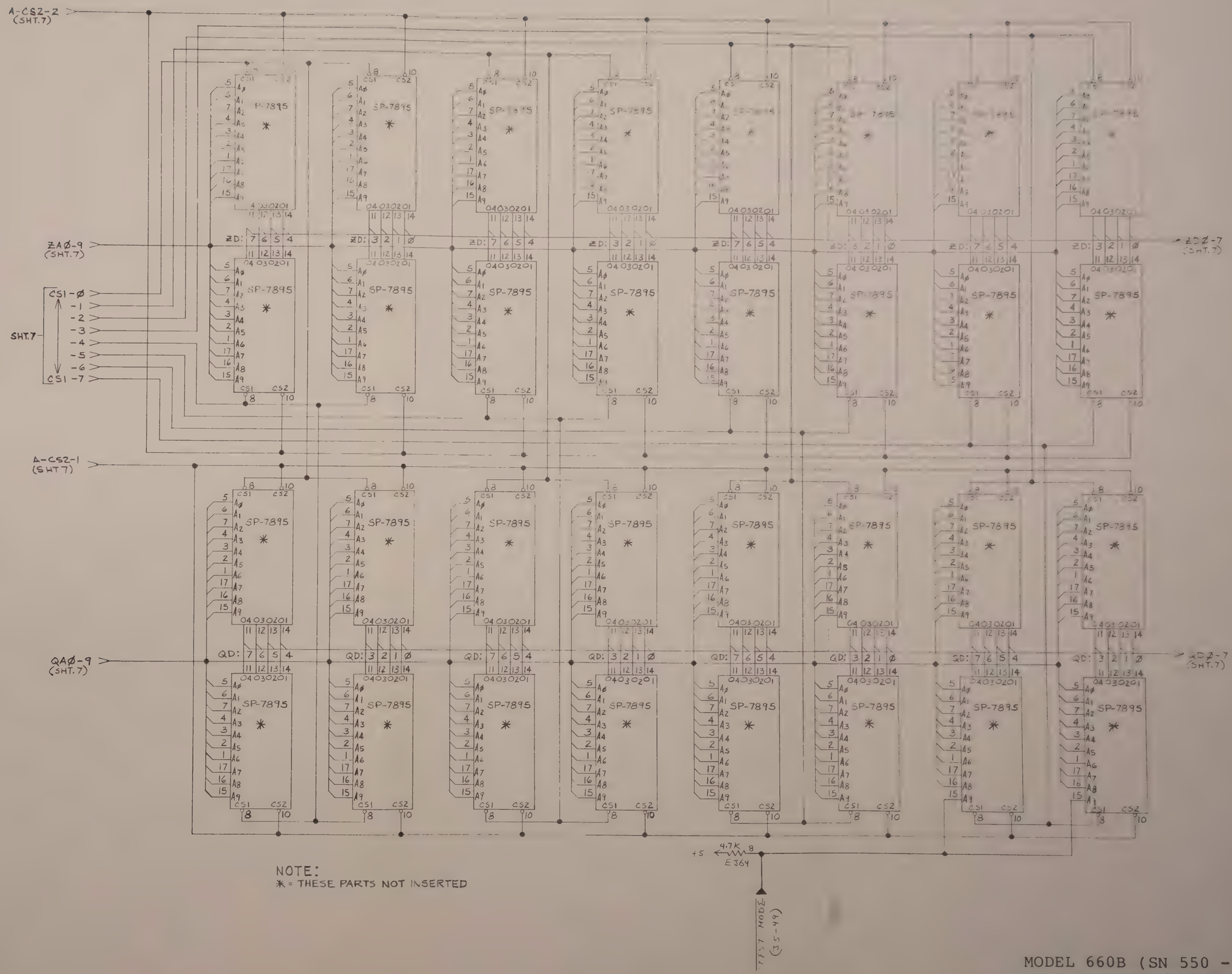
A-CS2-1 (THIS SHT.)

MDB:

MDB INT

NOTE:
✳ = THESE PARTS NOT INSERTED

MODEL 660B (SN 550 -
SLICE PROCESSOR/DISPLAY
100-SC-8701
SHEET 7 of 8 REV B
4-82




NOTE:
* = THESE PARTS NOT INSERTED

MODEL 660B (SN 550 - )
SLICE PROCESS/DISPLAY
100-SC-8701
SHEET 8 of 8 REV B
4-82

86124